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ORIGINAL ARTICLES.

A Recent Rhyolite-ash with Sponge-spicules and Diatoms in Malaya.

By J. B. Scrivenor.

(PLATES XXI–XXIII.)

IN 1928 the owner of the Tanjong Perak Rubber Estate, Dr. H. Trail Skae, noticed a white, porous, and friable rock near the Estate buildings and took specimens that were ultimately sent to the Geological Survey Department for report. The rock proved to be entirely new to British Malaya and of great interest, while in view of its complicated composition I suggested in a local publication that it should be called " Vitrite ". Dr. Skae registered the name " Vitrite " as a trade-mark for this rock, which has possible uses in commerce, but it has since been discovered that the word was used during the war by a Dutch firm for a particular kind of glass used in electrical work, so the name has to be abandoned, and the only attempt I have ever made to inflict a new name on petrologists has been signally defeated.

Tanjong Perak Estate is on the right bank of the Perak River opposite Kuala Plus, and about seventy miles upstream from the mouth of the Perak River. A high granite range lies to the west of the Estate, the position of which, and area over which the rhyolite-ash occurs being roughly indicated by a black mark on the accompanying map between the E and R of Perak. The Perak River, where it passes Tanjong Perak Estate, flows over a granite bed-rock. Until the big flood of 1926–7 the ash was not exposed on the river banks, but now it can be seen overlying sand and gravel, which, in turn, rest on the granite. Close to Dr. Skae's house a well was sunk through the rock for 29 feet before gravel was reached. This is the greatest thickness known as yet.

The rock is a mixture of minute angular fragments of (*a*) pumice, which often show a tubular structure and also contain spherulites, rarely a crystal of felspar ; (*b*) crystalline mineral-grains comprising perfectly fresh albite, quartz, biotite, tourmaline, zircon, rutile, ilmenite (not abundant), and a little brookite and hornblende (Dr. Ch. E. A. Harloff, of the Netherlands Indies Geological Survey,

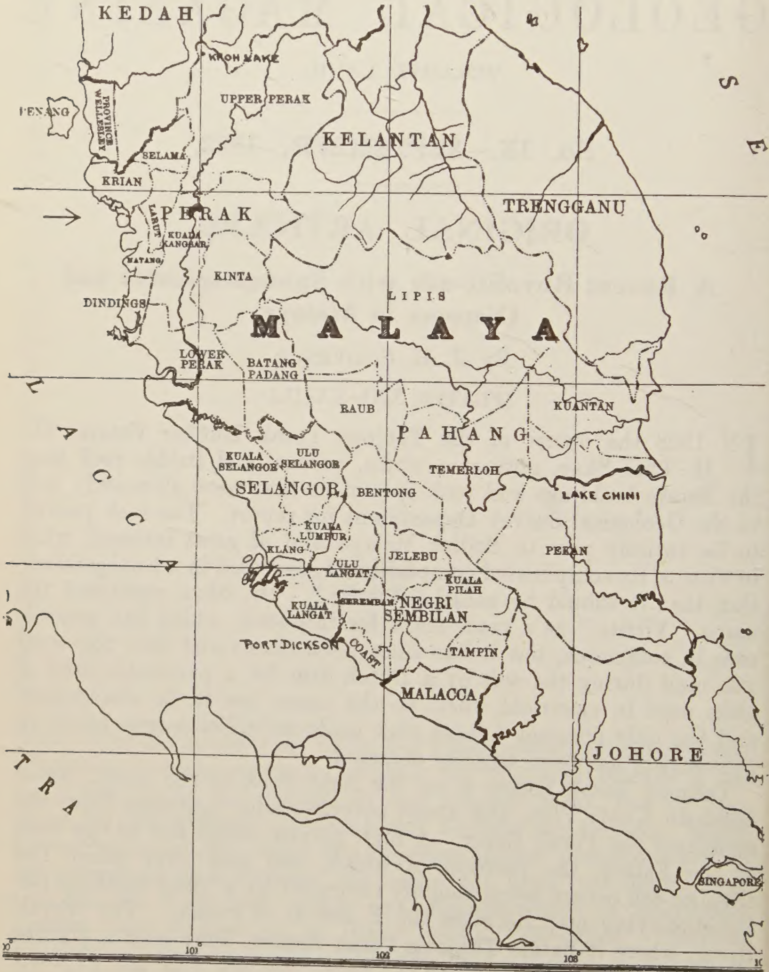

FIG. 1.—Map of Malaya. The arrow on the left side of the map points to the position of the deposit, between the E and R of Perak.

who kindly examined a specimen of the rock for me, detected inclusions of fluorite in the albite); and (*c*) bodies of organic origin consisting mostly of rod-like and spherical siliceous sponge-remains, irregularly shaped sponge-spicules, and some monaxons with sharp terminations (oxeate microrhabdi ?); and, less abundant, except in one case of rock collected at the landing-place on the river bank, diatom-frustules.

The proportions of pumice, mineral grains, and organic remains vary, but the pumice is always the most abundant. The proportion of mineral grains and sponge-spicules decreases with fineness in grain. Since the first specimens were collected Dr. Skae has given me further large samples which are much finer in grain than the original samples and contain very few organic bodies. The diatomaceous rock at the landing-place is judged to contain 75 per cent of pumice and mineral grains, the remaining 25 per cent being diatom-frustules and sponge-spicules.

The rock is fine-grained. The largest grain measured is one of pumice, its length being 1·25 mm. The longest rod-like spicule measured is ·15 mm. The greatest diameter measured on a spherical body is ·1 mm. In all friable specimens collected the bulk of the rock passes through a 120 mesh sieve. Dr. Skae has found that only slight treatment is needed to make it pass through a 200 mesh sieve.

In two places the grains of the rock were found to be cemented by chalcedony and sections could be ground down for microscopic study without difficulty. One such outcrop shows distinct stratification of fine and coarser material.

The organic bodies were recognized as being most probably sponge-remains, but as my knowledge of the *Porifera* is very limited I sent a specimen to the British Museum of Natural History, where they were examined by Mr. M. Burton. In view of the position of the deposit and the associated diatoms I had suggested that the sponges were freshwater species, but Mr. Burton considers them to be marine. His report, for which I am greatly indebted to him, is as follows:—

" The possible sponge elements found in the rock are of three kinds—(*a*) the ' rod-like bodies '; (*b*) spherasters; and (*c*) irregular, nodular, siliceous bodies.

" (*a*) Owing to the fact that in no case was a complete specimen found, it is impossible to use these bodies for the purpose of identification, except in conjunction with the other elements found. They might be the remains of any one of the score or so types of monaxon spicules.

" (*b*) There is little doubt that these spherasters belong to a species of *Tethya* (=*Donatia*) or *Stelletta*, and more probably the former. In this case the ' rod-like bodies ' could very easily be the remains of the strongyloxeate megascleres. The recent species of *Tethya* are marine, world-wide in distribution, found mostly in shallow water even between tide-marks, but often occurring in waters of several hundred fathoms. Frequently, they occur in ' beds ' to the exclusion of all other sponges.

" (*c*) These remains suggest the presence of Lithistid sponges, which are also shallow-water forms, rarely, if ever, occurring at depths greater than 100 fathoms to-day. Lithistids are confined to the warmer seas, and, again, occur in 'beds'.

"I can see no positive evidence of the presence of freshwater sponges and the only suggestive evidence is that of the 'rod-like bodies' which might be megascleres of such forms. On the other hand, spicules of similar form are found in hundreds of marine sponges, including the two types referred to above.

"In my view, there is every possibility that the deposit is marine in origin, and was probably formed in shallow, and most probably littoral, waters."

(Sgd.) M. Burton,
Assistant-Keeper, Zoological Dept.
British Museum (Nat. Hist.).

The plates accompanying this paper will give a better idea of the sponge-spicules than any description in words. Before receiving Mr. Burton's report I had submitted specimens to Mr. A. C. de Jongh, Director of the Netherlands Indies Geological Survey, and to Mr. J. H. Dennett, of the Agricultural Department, Federated Malay States. Referring to the rod-shaped spicules Mr. de Jongh wrote: "I may add that these same bodies are present in practically every soil sample taken in Java. When such samples are washed in the customary manner for mechanical analysis and the sand fractions sorted out and examined under the microscope in reflected light, these rods at once draw the attention by their milky appearance and sometimes opalizing colours." Mr. Dennett wrote :—"I have seen bodies such as you describe in various soils in Malaya, but not to the extent to which they occur in the specimen forwarded by you." At the time when Mr. Dennett wrote I was examining soil-samples for him and found some of these spicules in a sample from Malacca. These are illustrated in Plate XXIII, Figs. 2, 3, and 4. Under the impression that the sponges were freshwater species I also collected mud from Lake Chini, in Pahang, the only natural lake we have worthy of the name, and from an artificial lake at Kroh, in Upper Perak. In the latter I found abundant monaxons, some coloured brown, and spherasters (Plate XXIII, Figs. 5 and 6); in the Lake Chini mud I found no "rods" but abundant spicules with sharp terminations (microxeae) and minute spherasters much smaller than those in the rhyolite-ash. The Lake Chini mud also contains abundant broken diatom-frustules and numerous well-preserved specimens of a diatom I take to be *Melosira* (Plate XXIII, Figs. 7 and 8). Diatoms are rare in the specimens of Kroh Lake mud.

Plates XXI and XXII will give a general idea of the organic remains in the ash and the ash itself. Plate XXI, Fig. 1, shows pumice, mineral grains, and the monaxons well, and on the right a spheraster. In the lower part of the figure is a club-shaped

PLATE XXI.

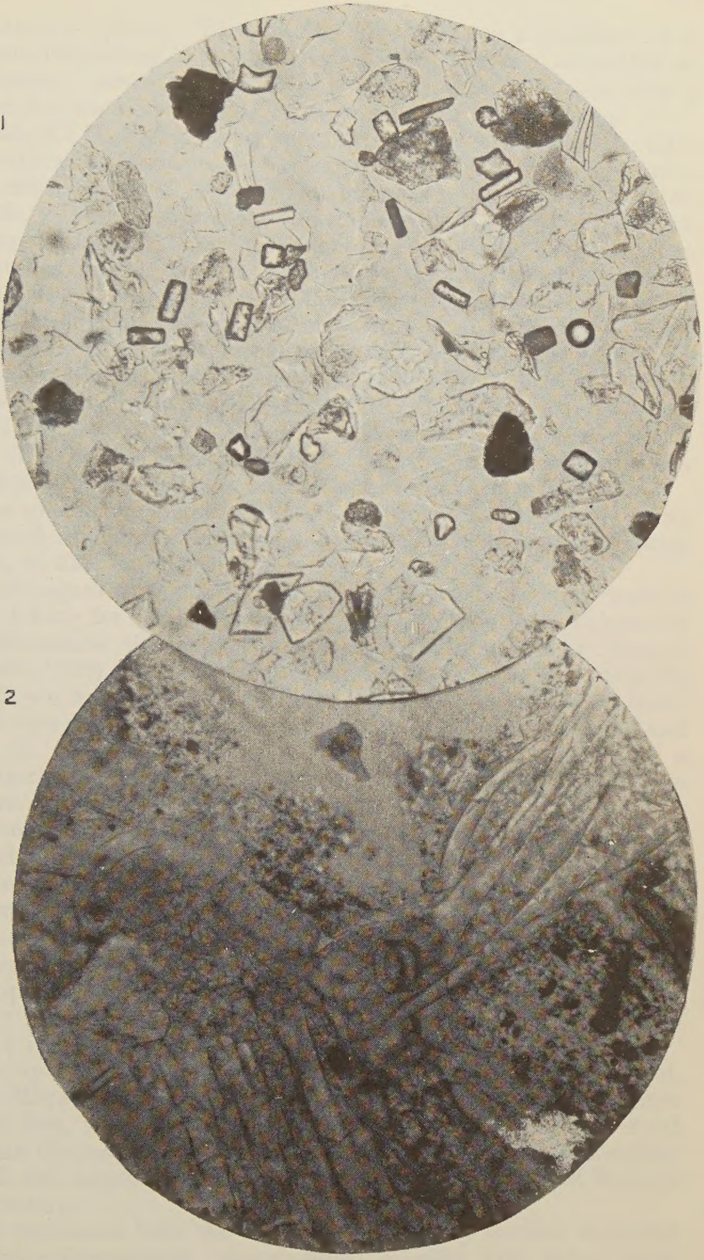

Fig. 1

Fig. 2

RHYOLITIC ASH FROM TANJONG PERAK, STATE OF PERAK, F.M.S.

[*To face p.* 388.

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(Lithistid ?) spicule. Plate XXI, Fig. 2, shows a specimen of a diatom, resembling, but not identical with, *Melosira*, embedded in chalcedony cementing pieces of tubular pumice. In one slide I found five such frustules lying close together in the matrix.

Plate XXII, Fig. 1, shows the pumice-fragments in section and a crystal of clear felspar embedded in pumice. Fig. 2 shows monaxons and mineral grains. Among the monaxons is a broken, pointed spicule. Fig. 3 is a highly magnified " rod-shaped " monaxon showing pitting. These monaxons are generally colourless but sometimes brown. Fig. 4 is a spheraster showing the rough surface. Both rods and spherasters are solid, isotropic, and have a refractive index lower than balsam. When heated in a muffle for an hour the rods in many cases developed an opaque opalescent centre and split down the long axis. Some spherasters became opaque. Figs. 5 and 6 show club-shaped (Lithistid ?) spicules ; compare Plate XXIII, Fig. 4. Plate XXII, Fig. 7, shows an object that may be part of a " tylote microrhabdus ". Fig. 8 is best described, as in the legend of the plate, as an " object of unknown nature ".

The spherasters are not all like that in Plate XXII, Fig. 4. Many are much smaller, knobbly, or spiny (cf. *Cambridge Natural History*, vol. i, p. 222, fig. 109 r).

With regard to the diatoms in the rhyolite-ash, the only detailed work I have for comparison is Mr. V. L. Eardley-Wilmot's memoir on Diatomite (Canada, Department of Mines, Mines Branch, No. 691, 1928), and except for one species, that figured in Plate XXI, Fig. 2, see no reason why all those in the ash should not be freshwater species, *Melosira* being one of them (*vide* op. cit., p. 41 and plate i). The exception is a ring-shaped diatom, suggesting a napkin-ring with a constriction round the centre. I will refer to it here as the " ring-diatom ".

A comparison between the organic remains in the rhyolite-ash and those in the finest sediment on the present sea-shores was obviously advisable, so I had specimens collected from the shore at Port Dickson (see map), and from the Dindings, not far from the ash and close to the mouth of the Perak River. The Port Dickson specimens were disappointing, affording only fragments of large sharp-pointed monaxons with hollow axes, and oval, spiny bodies closely resembling the fully developed microsclere of *Placospongia* figured in the *Cambridge Natural History*, vol. i, p. 233.

The specimens from the Dindings, however, are very different. Inche Mayah bin Latib, a Malay collector, took 10 specimens from Muroh Bay, which is sheltered by Pangkor Island (the right-hand cross on the map), and 7 from Nipah Bay, on the west of Pangkor Island, and exposed to the heaviest seas that the Straits of Malacca can produce.

The specimens from the sheltered Muroh Bay contain abundant calcareous foraminifera, sharp-pointed spicules with hollow axes, fewer solid monaxons like those in the ash, numerous small spherasters, and irregular lithistid spicules. Diatoms are abundant, the commonest being the ring-diatom mentioned above as occurring in the ash. Discoid, triangular, and other stranger forms of diatoms occur also, which have not been found in the ash. The evidence here, therefore, is that a number of presumably marine species of diatoms occur in Muroh Bay which do not occur in the ash; but one species, the ring-diatom, occurs in both. It is, I think, too abundant to be regarded as a freshwater species washed down the Perak and Lumut Rivers and stranded on the beach.

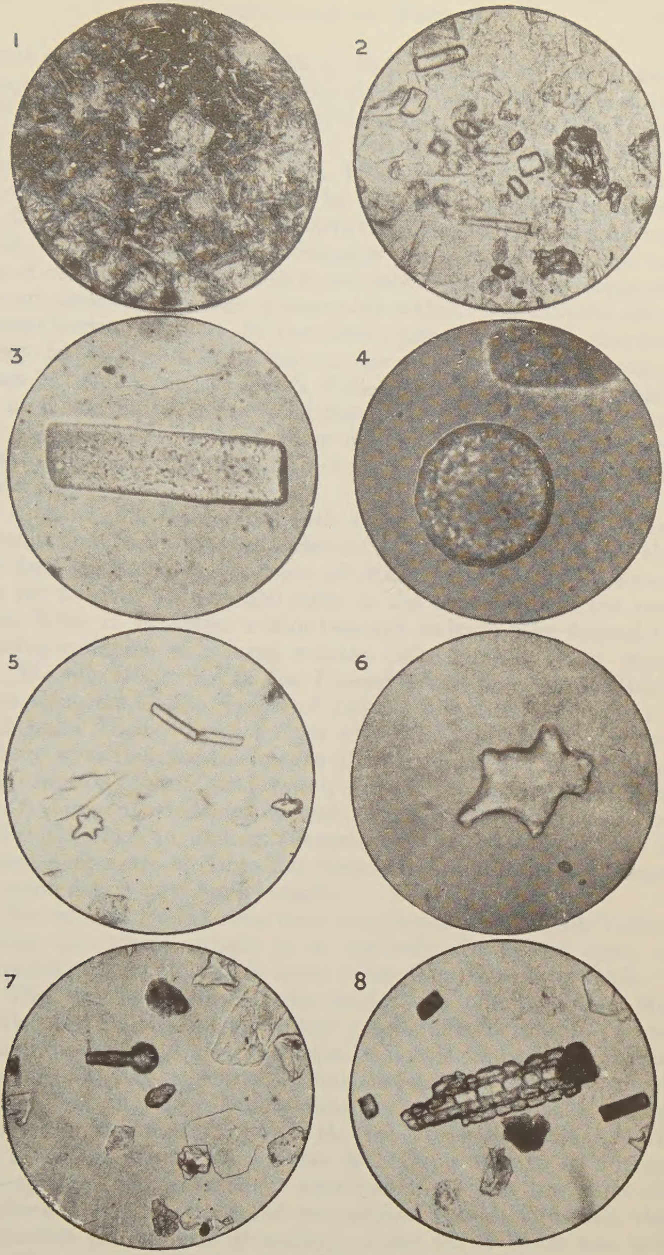
The specimens from the exposed Nipah Bay differ in the comparative rarity of fragile foraminifera and diatoms. Solid monaxons and spherasters like those in the ash and irregular spicules are more abundant than in Muroh Bay. In seven slides only one ring-diatom was found; but the fact that it occurs here at all is additional evidence of its being a marine species. Sharp-pointed spicules are abundant. The solid monaxons are sometimes coloured brown.

The solid monaxons and spherasters in the rhyolite-ash are more numerous in the first specimens examined and on the whole larger and better formed than those in Nipah Bay. In the specimens from the latter locality I did not see any very short monaxons like those figured in Plate XXII, Fig. 2, nor any club-shaped spicules exactly like those figured in Plate XXII, Figs. 5 and 6. Monaxons like that in Plate XXIII, Fig. 2, occur. These specimens from Nipah Bay, however, in spite of these slight differences, afford good evidence in support of Mr. Burton's opinion that the spicules in the ash are of marine origin.

When considering the history of this rock we have to take account of the following factors:—(1) a narrow river-valley with high mountains rising steeply on either side; (2) 29 feet of rhyolite-ash overlying alluvium; (3) mineral grains; (4) sponge-remains identified on good authority as marine, some of which are found in soil-samples over wide areas in Java and Malaya, and also in two lakes in Malaya; (5) diatoms similar to the freshwater forms figured in Mr. Eardley-Wilmot's memoir on Diatomite.

(1) It is not proposed to discuss here at length the changes of sea-level in the East Indies during Pleistocene and Recent times, but that there have been great changes is, I think, beyond question. Evidence in the East Indies makes me a firm believer in Daly's "glacial control" theory, and the formation of Molengraaff's "Sunda-land" during the Pleistocene glaciation, when the sea-level was lowered by the accumulation of ice at the poles. The Perak River Valley dates back at least to Pleistocene times, when the Straits of Malacca were dry land, and the Perak River joined others from what is now Sumatra.

When the ice melted, Sunda-land was submerged, as is proved by the "drowned" tin-bearing valleys of Singkep and Banka, and the sea rose higher than its present level. Daly (*American*



Microphotographs of Rhyolite-ash and Included Bodies.

[*To face p.* 390.

Journal of Science, vol. x, 1925, p. 293) thinks there has been a subsequent fall of sea-level in post-glacial times of about 6 metres (19·68 feet), but in Malaya, a part of the stable area of the East Indies, there is evidence of a greater fall. I have seen raised beaches 50 feet above the present sea-level. Dr. Wilhelm Credner tells me that in Lower Siam, close to Malaya, he has seen marks of an old sea-level, 25–30 metres (say 90 feet) above the present level on a limestone and on a granite cliff; and zoologists tell me that the flora and fauna of certain hilly tracts show evidence of having been separated in recent times by a barrier, presumably water. The rhyolite-ash at its lowest horizon is about 150 feet above present sea-level, therefore we only have to go a little beyond the evidence cited to imagine the sea extending up the Perak Valley and lapping on a granite shore at Kuala Plus. A rise of 200 feet above the present level would carry the shore-line much farther up the Perak Valley and give sufficient depth for the deposition of the present deposit at Tanjong Perak Estate.

(2) Where did the rhyolite-ash come from? In the Malay Peninsula there is no trace of a Recent or Tertiary volcano and this is the first ash found lying above alluvium. But a possible source is not far to seek. About 250 miles to the south-west of the rock is Lake Toba, in Sumatra, a lake believed to have been formed by successive collapses of a large volcano (*vide* a forthcoming paper by R. W. van Bemmelen in the *Proceedings* of the Fourth Pacific Science Congress, "The Origin of Lake Toba (North Sumatra)". Round Lake Toba "liparitic" or rhyolite-ashes are widespread and there were two possible means of transport of pumice to Perak during eruption; wind, and water, on which pumice would float and drift across if wind and current were favourable. There is no difficulty therefore in finding a source for the rhyolite-ash, but it is strange that more of it has not been found, and further evidence of its existence is now being sought.

(3) The mineral grains come from the granite of the Perak Valley, excepting the albite, which is so perfectly devoid of signs of decomposition that I think it must come from the rhyolite-ash.

(4) The sponge-remains, if the reader will refer again to Mr. Burton's report, do not present any great difficulty except in one particular. Accepting his conclusion, which is strongly supported by the Nipah Bay specimens, that they are marine, we must remember that they are shallow-water forms, most of them living even between tide-marks. So, if the sea extended up the Perak Valley as far as Kuala Plus, there is nothing strange in finding marine sponge-skeletons there: conversely, the fact that they do occur there is evidence that the sea reached Kuala Plus since the first alluvium (Pleistocene or earlier), of the Perak River was laid down. The general distribution of the monaxons in the soils of Java and Malaya is easily explained by the recession of the sea to the present level and distribution by wind and rivers. These

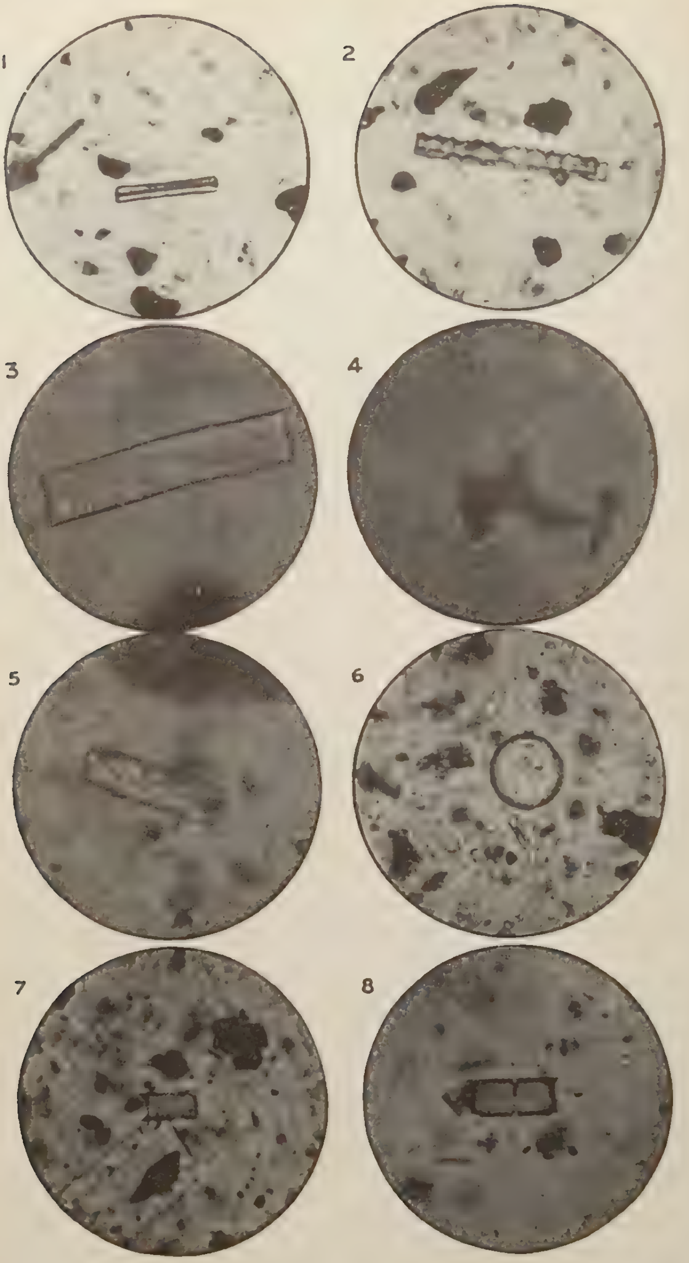
structures are not only very minute and easily moved, but they are also tough and insoluble compared with calcareous organisms, which, in this warm, wet, tropical country do not persist long (in geological time). This is probably the reason why no calcareous matter has been found in the rhyolite-ash : if it ever existed it has been dissolved away.

A rise in sea-level of 200 feet would put Lake Chini under the sea. The spicules there may be in part or wholly freshwater, but marine spicules might have been deposited on the site of the lake. In this connection and in view of my suggestion that the sponge remains in the ash are from freshwater sponges it is interesting to note that so far freshwater sponges have proved very scarce in the Malay Peninsula. In the *Memoirs of the Asiatic Society of Bengal*, vol. vi, part iv, 1918, p. 207, N. Annandale described a freshwater sponge (*Ephidatia blembingia*) from " Legeh " now part of Lower Siam adjoining Kelantan. Annandale said that very few freshwater sponges had been found in the Malay Peninsula and none in the Federated Malay States or Straits Settlements. " There can be no doubt, therefore, that in most parts of Malaya, as in Ceylon, some unknown obstacle to the growth of sponges is widespread in fresh water . . . four species are therefore; now known to occur in the Eastern Peninsular provinces of Siam."

Mr. Cedric Dover, writing in *Nature* for 28th September, 1929, p. 499, on the freshwater fauna of the Malay Peninsula, says that no hydrozoa or sponges have yet been found. " Sponges are entirely absent " (op. cit., p. 500) ; but Mr. Dover obviously does not refer to the Siamese portion of the Malay Peninsula.

The spicules in the artificial lake at Kroh, however, do present a difficulty, because the lake is 1,000 feet above sea-level and the spicules are not rare. If marine, it is hard to understand how they arrived. No freshwater sponge has been found in the lake, however, and the lake was made by damming a valley for tin-mining only about fifty years ago, so the opportunity for a large accumulation of freshwater spicules has not been great. A rise in sea-level of 200 feet would bring the sea within 10 miles of Kroh and it is possible that wind blew the spicules into the Kroh Valley from the lower ground. They may even be derived from denuded pre-Pleistocene marine beds. In the absence of any proof of the existence of sponges in the lake these appear to be the only possible explanations, a rise of 1,000 feet beyond the present sea-level owing to the melting of the polar ice being beyond a reasonable claim.

(5) The diatoms, even if they were all freshwater species, need not contradict the evidence of the marine sponges. If the ash was deposited on a shore-line, water and wind might very well bring about a mixture of such minute marine and freshwater organisms, but one diatom at least in the ash appears to be marine. How exactly the ash was deposited is doubtful. The extreme fineness



Microphotographs of Organisms from Soil and Lakes in Malaya.

To face p. 393.]

and angularity of the bulk of it suggests that it was wind-borne, but if the sea were now at Kuala Plus it would form a long, narrow fiord between granite mountains, and if wind drove floating pumice up the fiord it would be broken to pieces gradually by the waves on the beach at its termination.

I must confess that this suggested history of the rock is highly speculative, though interesting, but there does seem to be evidence now of marine organisms far inland in the Malay Peninsula, and about 200 feet above the present sea-level, and also an explanation of the widespread occurrence of marine sponge-spicules in the soils of Java and Malaya.

EXPLANATION OF PLATES XXI–XXIII.

PLATE XXI. RHYOLITIC ASH FROM TANJONG PERAK, STATE OF PERAK, F.M.S.

FIG.

1.—Ash broken up and mounted in balsam, showing fragments of pumice, mineral grains, and monaxon spicules; also one spheraster on the right, the spicules and spheraster having a refractive index much lower than the balsam. × 100.

2.—Section of compact ash, showing the tubular nature of the pumice and a diatom embedded in the rock. × 550.

PLATE XXII. MICROPHOTOGRAPHS OF THE RHYOLITE-ASH AND INCLUDED BODIES.

1.—Section of compact ash showing pumice and a crystal of felspar in pumice. × 40.
2.—Monaxon spicules in ash broken up. × 75.
3.—A monaxon spicule showing pitting. × 280.
4.—A spheraster showing pitting. × 280.
5.—Monaxon and club-shaped (Lithistid ?) spicules. × 75.
6.—A club-shaped (Lithistid ?) spicule highly magnified. × 280.
7.—Another club-shaped spicule (part of a tylote microrhabdus ?). × 75.
8.—An object of unknown nature. × 75.

PLATE XXIII. MICROPHOTOGRAPHS OF ORGANISMS FROM SOIL AND LAKES IN MALAYA.

1.—A diatom in soil from a rice-field near the sea, Malacca. × 75.
2.—A monaxon spicule; same locality. × 75.
3.—A monaxon spicule; same locality. × 280.
4.—A club-shaped object; same locality. × 280.
5.—A monaxon spicule from a small artificial lake at Kroh, 1,000 feet above sea-level. × 280.
6.—A spheraster; same locality. × 280
7.—A diatom (*Melosira* ?) from Lake Chini, Pahang. × 625.
8.—A diatom (*Melosira* ?); same locality. × 625.

An Upper Carboniferous Fauna from the Amotape Mountains, North-Western Peru.

(*Continued from Vol. LXV, p.* 301.)

By H. Dighton Thomas, M.A., Ph.D., F.G.S.

(PLATE XXIV.)

GASTEROPODA.

FAMILY BELLEROPHONTIDAE.

Genus Bellerophon Montfort.

Bellerophon sp. cf. *crassus* Meek and Worthen.

(Pl. XXIV, Figs. 1, 1*a*.)

THERE are two specimens of *Bellerophon* in the collection which may be co-specific—one is fairly well preserved, though a little distorted, and the other is worn.

Description.—The shell is of medium size, and involute, with the umbilicus very small. The width of the whorls is equal to about two-thirds of their diameter, though the last whorl expands fairly rapidly; the height of the aperture is equal to about one-third to one-half of its width. At the aperture the shell margin is rolled and thickened. The border of the umbilicus is rather rapidly rounded. The dorsal surface is gently convex, its curvature being interrupted by the median slit-band, which is prominent and raised, though not very wide. The surface is ornamented with numerous fine, closely-set transverse ribs, which are slightly convex forwards.

Remarks.—The better preserved specimen appears to be very close to, if not identical with, *B. crassus* M. and W. (**45**, p. 385, pl. xxxi, figs. 16*a*, *b*), though the original figures indicate a rather narrower form. The shape of the Peruvian specimen approaches very closely to the variety described by Girty from the Wewoka formation of Oklahoma (**12**, p. 164, pl. xix, figs. 1–3*a*); the ornamentation is less marked than in those forms referred to the species by him in the Guadalupian fauna (**66**, pp. 479–81, pl. xxix, fig. 16). *B. crassus* M. and W. is recorded from the Rio Tapajos region of Brazil by Derby (**2**, p. 499). Meyer also mentions casts of a large species of *Bellerophon* from South Peru (**78**, p. 635).

Localities.—Steel Hill, Pariñas Quebrada; Gramadal Quebrada (east limb of fold), about 3 miles from its junction with the Pariñas Quebrada.

Bellerophon sp.

Description.—There are three internal moulds of a large species of *Bellerophon*, which is involute and globular, with a low transverse aperture. The umbilicus is very small and its margin rounded. The only markings on the moulds are well-marked constrictions. There are four to a whorl, and they curve slightly forwards as they cross the dorsum. It is quite impossible to refer these moulds to any species.

Localities.—Goniatite Bed, Pariñas Quebrada ; Steel Hill, Pariñas Quebrada.

Genus Bucanopsis Ulrich.[1]

Bucanopsis multiscalpta sp. nov.

(Pl. XXIV, Figs. 2–3*a*.)

Five specimens comprise the material on which this species is based.

Description.—The shell is small and involute, with the greatest diameter equal to about one and a half times the greatest thickness. The whorls increase slowly in size so that the dorsal view shows the sides only slightly divergent. The aperture is lunate in outline. The umbilicus is small, with the umbilical shoulders rather rapidly rounded. The sides and broad dorsum are evenly and broadly rounded. A well-marked, relatively high, rounded, median slit-band of moderate width traverses the whorls. The whole surface of the test is ornamented with more than sixty very fine, low, rounded, spiral ribs, which are separated by narrow interspaces, while about ten slightly finer ones traverse the median ridge. In addition there are fine radial ribs which curve gently forwards over the dorso-lateral border, but bend slowly backwards as they approach the slit-band. It is not certain whether they cross this or not. The shell substance is thin.

Remarks.—This species is distinguished by the comparatively slow rate of increase of the size of the whorls, by the straight sides viewed from the dorsum, by the very fine ornamentation, and by the raised slit-band. The first two mentioned characters separate it from *B. marcouana* Gein. sp. (**5**, p. 7, pl. i, fig. 12 ; **21**, pp. 226–7, pl. iv, fig. 17 ; pl. xi, figs. 3*a*, *b*) and from *B. meekiana* Swallow sp. (**12**, pp. 169–72, pl. xx, figs. 4–6). Of Indian forms *B. angustifasciata* Waagen (**29**, pp. 152–3, pl. xiii, fig. 6) and *B. integra* Waagen (**29**, p. 153–4, pl. xiv, fig. 5) may be compared, but both differ in possessing slit-bands which are scarcely raised above the rest of the shell and in being more widely umbilicate than *B. multiscalpta*. The ornamentation of the former is very similar. The striation is much finer in the Peruvian species than in most of the other members of the genus.

Locality.—Goniatite Bed, Pariñas Quebrada.

Genus Euphemus M'Coy.

Euphemus carbonarius (Cox).

(Pl. XXIV, Figs. 4–4*a*.)

1857. *Bellerophon carbonarius*, Cox, Kentucky Geol. Rept., vol. iii, p. 562.
1894. *Bellerophon carbonarius*, Derby, Journ. Geol., vol. ii, p. 499.

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[1] *Vide* Ulrich (87, p. 853).

1897. *Euphemus carbonarius,* Ulrich, Minnesota Geol. and Nat. Hist. Surv. Final Rept., vol. iii, pt. ii, p. 855.
1915. *Euphemus carbonarius,* Girty, U.S.G.S. Bull. 544, pp. 174–6, pl. xxi, figs. 1–3*b* (and for synonymy).
1922. *Euphemus carbonarius,* Morningstar, Geol. Surv. Ohio, 4th ser., Bull. 25, p. 249, pl. xv, figs. 4, 5.

This species is represented by one specimen which is almost entire, but slightly distorted.

Description.—The shell is globular, with a regularly rounded dorsum. The umbilicus is small and shallow with its borders rounded, though they appear to show a tendency to become slightly angular towards the aperture. There, too, the dorsum seems to flatten somewhat, but as this part is slightly distorted it is impossible to state this definitely. For a short distance the outer whorl shows the characteristic spiral ornamentation but anterior to this it is smooth. The spiral lirae, about twenty in number, are thin and rounded, and are separated by concave interspaces a little wider than themselves. The smooth anterior part occupies about one half of a whorl (there is very little of it broken away in the specimen).

Remarks.—The characters of the single specimen agree very well with the descriptions and figures of the species given by Cox, Girty, Morningstar, etc. (*opp. sup. cit.*), and there can be no doubt as to its belonging to Cox's species. Derby mentions *E. carbonarius* as occurring in Brazil (*loc. cit.*). The species has been described from the Upper Carboniferous of Samara by Stuckenberg (**84**, p. 101, pl. xi, fig. 17), from the Upper Carboniferous of Chitral and the Pamirs by Cowper Reed (**50**, pp. 92–3, pl. ix, fig. 9), and by Toula from Barents Island (**85**, p. 544). Hind (**71**, pp. 355–6) considered Cox's species identical with *E. d'Orbignyi* (Port.), but the specimen he figured (**71**, pl. ii, figs. 57–8) differs considerably from that from the Amotape Mountains. The only other species of the genus previously recorded from South American Carboniferous rocks are the forms referred by Salter (**82**, p. 64, pl. iv, fig. 6) to *Bellerophon* sp., which, he says, is a close ally of *B. urei* Fleming (and hence presumably belonging to *Euphemus* and possibly identical with *E. carbonarius*), and by Douglas to *E.* sp. cf. *indicus* Waagen (**64**, pp. 31, 36–7, pl. viii, fig. 5). Both come from Bolivia.

Locality.—Steel Hill, Pariñas Quebrada.

FAMILY EUOMPHALIDAE.

Genus Euomphalus Sowerby.

Euomphalus browni sp. nov.

(Pl. XXIV, Figs. 5–5*b*.)

In addition to eight well-preserved specimens of the species there are many others less perfect. Except for one rather poor specimen from Gramadal Quebrada, all of them come from the "Goniatite Bed"

Description.—The shell is of medium size and consists of from four to five whorls, of which the last increases more rapidly than the others. All are coiled in one plane, though the last whorl tends to rise[1] slightly out of it. The whorls are trapezoidal in section, and form an evolute spiral, with no overlap of the inner whorls by the outer ones on either the upper or lower surfaces, which are equally and gently concave. The suture lines are quite definite, though the slope of the upper surface of the shell is scarcely affected by them. From the suture line the upper surface of the whorls is inclined slowly upwards to a fairly sharp carina, which is situated at a distance from the suture equal to two-thirds of the diameter of the whorl. The carina becomes rounded on the last whorl, though, owing to the adherence of a thin film of rock which is removed only with difficulty, it may there assume a false angularity.

On the inner side of the carina there may occur a very obscure furrow on the outer whorl. The outer surface of the whorl forms a gently convex curve and meets the short flat inferior surface in another ridge, almost vertically below the upper one, though placed slightly nearer the outer margin. This ridge is angular on the inner whorls but in the adult becomes rounded.

The shell is ornamented with numerous, fine, closely-set, transverse striae. On the upper surface they are straight or only very slightly convex to the aperture, and curve backwards as they cross the upper carina. From this they are inclined backwards on the outer surface towards the lower ridge, although remaining convex to the aperture. Over most of the inferior face of the whorl they are straight, but they curve gently forwards as they approach its inner margin.

Remarks.—This species is very close to *E. subcircularis* Mansuy from Yunnan (**73**, pp. 105–6, pl. xix, figs. 3*a–d*), which is also recorded from Argentina by Cowper Reed (**27**, p. 143, pl. xv, figs. 1, 2, 4). It differs from that species, however, in its more concave upper surface and the smaller overlap on the lower surface. The inferior carina is better defined in the Peruvian species. *E. utahensis* Hall and Whitfield (**41**, pp. 259–60, pl. iv, figs. 20–3), from the Lower Carboniferous is similar but again the overlap on its lower side is greater than in *E. browni.*

Meyer (**78**, p. 620), records *E. subquadratus* Meek and Worthen from Bolivia ; the Amotape species differs from this (**77**, pp. 605–7, pl. xxix, figs. 12, 13), in the upper carina in the adult whorl being rounder and not nodose and in the outer margin being more curved. *E. antiquus* d'Orb. sp. (**26**, p. 42, pl. xii, figs. 1–3 ; **63**, p. 281), and *E. perversa* d'Orb., both from the region of Lake Titicaca, are quite distinct from the Peruvian species.

Among Russian representatives of the genus the species referred to as *E.* sp. cf. *tabulatus* Phill. by Stuckenberg may be compared, but its whorls are distinctly angulated above and below, and the outer wall is flatter (**84**, pp. 104, 143, pl. xii, figs. 23*a*–c).

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[1] The coiling is assumed to be dextral.

Localities.—Goniatite Bed, Pariñas Quebrada; Gramadal Quebrada (east limb of fold), about 3 miles from its junction with the Pariñas Quebrada.

FAMILY PLEUROTOMARIIDAE.

Genus Pleurotomaria Sowerby.

Pleurotomaria amotapensis sp. nov.

(Pl. XXIV, Figs. 6, 6*a*.)

One of the commonest fossils in the whole collection is represented by this species. There are forty specimens—some are internal moulds, but many have most of the test preserved.

Description.—The shell is of medium size, conical, subtrochiform, with the apical angle about 85°: in one or two cases it slightly exceeds a right angle. The whorls number four or five, with the last whorl equal to the height of the spire. The apical face is flattened from the suture line (which is not sunken) to the well-defined, slightly concave, narrow slit-band, the edges of which are raised somewhat. Below the band the outer wall is flat and vertical, and meets the very slightly convex base in a definite though rounded angle. Near the aperture, however, the outer wall is more rounded and the base convex. The surface is ornamented with numerous, fine, closely-arranged, spiral ribs. On the apical face there are nine of these fine ribs, on the vertical face below the slit-band there are eight, while on the lower surface there are about ten. Near the umbilicus these ribs become obsolete. On well-preserved specimens extremely small tubercles occur where closely-set, fine, transverse ribs cross the spiral lines. Frequently these transverse ribs are not seen. The aperture is sub-circular.

Remarks.—This species is very close indeed to *P. argentina* Reed from Barreal (**27**, p. 144, pl. xv, figs. 3*a*–*c*), and it was only after some hesitation that it was separated from that form. The Peruvian specimens, however, may be distinguished by their smaller size, larger spiral angle, greater equality of length and diameter, steeper lateral surface of the whorls, and finer ornamentation. In not one instance out of the large number of Amotape specimens does the size become as large as that of Cowper Reed's species, nor does the spiral angle become as small as in his specimens. *P. grayvillensis* Norwood and Pratten, a species occurring in North American Carboniferous faunas (**81**, p. 75, pl. ix, figs. 7*a*, *b*; **12**, pp. 149–52, pl. xxxiii, figs. 2–8), is very near to *P. amotapensis*, but the former species has strong transverse lines crossing the revolving ribs, and more prominent spinose tubercles. Very closely allied, too, is *P. marcouana* Gein. sp. (**5**, p. 10, pl. i, fig. 10), and especially the form figured by Fredericks from the Upper Carboniferous of Russia

(**65**, pp. 16, 105, pl. i, fig. 1), but the latter may be distinguished by the transverse folds on the earlier whorls.

Locality.—Goniatite Bed, Pariñas Quebrada.

Pleurotomaria sp.

Description.—There is one specimen of a *Pleurotomaria* which differs from those just described. It is crushed, and not very well preserved so that a complete description is impossible. The shell is medium in size, with a spiral angle of about 80°. The whorls are five in number with flat apical faces, and have a well-marked sunken slit-band. The ornamentation is generally effaced but on the lower whorl there are numerous, transverse striae.

Remarks.—This species seems to differ from the preceding in its size and in the more angular whorls.

Locality.—Crinoid Beds, Pariñas Quebrada (east of Cerro Chaleco).

CONULARIDA.

FAMILY CONULARIIDAE.

Conularia sp. aff. *crustula* White.

(Pl. XXIV, Figs. 7, 8.)

Two specimens represent this species.

Description.—The shell has a regularly conical shape, which tapers very gradually, and a nearly rectangular cross-section. The sides are almost flat, though near the angles where adjacent sides meet the surfaces become slightly curved. Each face is traversed longitudinally by a shallow median furrow, while at each of the angles between the faces is a well-marked groove. The ornamentation consists of transverse costae, which are well-marked though narrow, and which over most of the surface number nine or ten to 5 mms. of the length. They are subangular, and rise rather rapidly from the nearly flat inter-costal spaces which are between three and four times as wide as the costae. The latter are not continuous across the faces; instead, each of these really has two sets of costae, which generally alternate slightly on either side of the median furrow, though in some cases they meet. The angle between the two sets at the median furrow is widely obtuse. The costae run down the sides of the groove at the interfacial angles, but alternate to some extent on the sides of it, though in some instances the ribs meet. The intercostal spaces are occupied by two or three fine growth-striae.

Remarks.—This species is very close to *C. crustula* White (**88**, p. 170, pl. xlii, fig. 4*a*; **12**, pp. 42–3, pl. v, figs. 4, 5), from which it differs in certain details. Thus in the Peruvian form the costae alternate more frequently than in White's species, while the angle between them on each face is somewhat less.

Locality.—Crinoid Beds, Pariñas Quebrada (east of Cerro Chaleco).

BRACHIOPODA.

INARTICULATA.

NEOTREMATA.

FAMILY TREMATIDAE.

Genus Lingulidiscina Whitfield.

Lingulidiscina ? *sera* sp. nov.

(Pl. XXIV, Figs. 9–10.)

Ten curious inarticulate brachiopods occur among the fauna from Gramadal Quebrada, associated with others of the normal Carboniferous aspect. The shell substance has the usual appearance of that of the Inarticulata. All the specimens are dorsal valves—in no case is even a fragment of a ventral valve present.

Description.—The dorsal valve attains a large size, is convex, and is almost circular in outline, being slightly elongated in the postero-anterior direction, and a little broader anteriorly than posteriorly. All the specimens are somewhat unsymmetrical, but in most cases this is largely explicable by the crushing which has obviously affected them. The holotype specimen is only slightly inequilateral from this cause. The inflation is moderate and reaches a maximum at a distance from the posterior margin equal to about one-quarter of the length. The umbo, which is small, but well-marked and prominent, is situated almost at and slightly above the posterior border; indeed, only a very narrow part of the valve separates the two.

The surface is practically smooth, the only ornamentation consisting of numerous, very fine, concentric striae, which are more marked anteriorly. Sometimes, where exfoliation of the rather thin shell has taken place, fine radiating striae are shown, especially in the anterior part, a common feature of orbiculoid types of shells.

In a few instances where the shell-substance has been removed along the axis of the valves, impressions on the internal mould are shown (Pl. XXIV, Fig. 10). These consist of two shallow linear grooves which run from about the centre towards the umbo and which are separated by a narrow ridge. At a distance from the umbo equal to one-fifth of the length of the valve the depressions terminate. At the same time as they disappear a narrow groove on the internal mould replaces the ridge which separates them. This groove reaches nearly to the umbo; it may actually reach it, but this is not quite clear. This last-mentioned groove on the internal mould corresponds to a short septum on the interior of the valve, while, where this ends anteriorly, two low, parallel and adjacent ridges arise on the anterior of the shell and extend forwards as far as the centre. These median ridges doubtless are analogous to the two similar ones found in *Roemerella* Hall and Clarke (**70**, p. 137; **12**, pp. 51–3, pl. vi, figs. 1–10*a*), and probably served a similar function for the attachment of muscles. The ventral valve is unknown.

Remarks.—The genus *Lingulidiscina*[1] (**91**, p. 122, figs. 1–8), used here in the restricted sense as synonymous with *Oehlertella* Hall (**70**, pp. 132–3), and not in the wider usage of Girty (**11**, pp. 37–8) who employs the term as the equivalent of *Orbiculoidea* auctt., is typically a Devonian and Lower Carboniferous genus. It is unfortunate that the ventral valve of the Peruvian species is unknown, but the configuration and nature of the dorsal valve are suggestive of *Lingulidiscina.* The internal structures of that genus (*sensu stricto*) are unknown, so that a comparison with those of the Amotape form is impossible. Should the latter prove from its ventral valve to be congeneric with *Lingulidiscina*, it is an interesting extension of its range in space and time, though, as noted below, species which are probably referable to the genus occur in the Upper Carboniferous.

The size, shape and ornamentation of *L.* ? *sera* separate it not only from *L. exilis* (Hall), a Devonian form, but also from the Carboniferous species *L. pleurites* Meek sp. (**76**, p. 278, pl. xiv, fig. 2 ; **70**, p. 132, pl. 4E, figs. 21–4), *L. connata* Walcott sp. (**30**, p. 214, pl. vii, fig. 3), and *L. newberryi* Hall sp.[2] (69, p. 25, pl. i, figs. 10, 11), and its varieties (**11**, pp. 38–41, pl. ii, figs. 1–8).

Two North American Upper Carboniferous inarticulate brachiopods may belong to *Lingulidiscina.* Schuchert (**83**, p. 280), has made that suggestion with regard to *Orbiculoidea munda* Miller and Gurley (**79**, p. 71, pl. vii, figs. 6, 7). That species differs from *L.* ? *sera* in being smaller and in being oval in shape.

Recently, Miss Morningstar has described from the Lower Pennsylvanian of Ohio a form that she refers to *Orbiculoidea*, viz., *O. stoutella* (**80**, pp. 173–4, pl. vii, figs. 5–8). This species is very similar in configuration to *L.*? *sera* but differs in being slightly broader than long and in being ornamented with fine but irregular concentric striae. The internal structure, too, is different. There is no suggestion in *L.*? *sera* of the rhombohedral visceral area that she mentions. On the other hand the two median ridges of the Peruvian species do not seem to be present in *O.* ? *stoutella.* These differences in internal structure probably indicate that the two species belong to different genera.

Locality.—Gramadal Quebrada (east limb of fold), about 3 miles from its junction with the Pariñas Quebrada.

FAMILY DISCINIDAE.

Genus ORBICULOIDEA d'Orbigny.

Attention has already been called, e.g. by Girty (**67**, p. 18 ; **11**, p. 37), to the fact that there are objections to the use of

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[1] Objection to the validity of *Lingulidiscina* has been raised by G. H. Girty, *Journ. Washington Acad. Sci.*, xviii, 9, 1928, pp. 241–9.

[2] This species was apparently accidentally referred to *Lingulidiscina*, by Schuchert—*vide* G. H. Girty, *Journ. Washington Acad. Sci.*, xviii, 5, 1928, pp. 128–42.

Orbiculoidea as a generic term, but, failing its replacement by some other, it is used here in its customarily accepted sense.[1]

Orbiculoidea meekana (Whitfield).

(Pl. XXIV, Figs. 11–12.)

1882. *Discina meekana* Whitfield, Ann. N.Y. Acad. Nat. Sci., vol. ii, p. 228.
1891. *Discina meekana* Whitfield, ibid., vol. v, p. 598, pl. xv, figs. 1–3.
1895. *Discina meekana* Whitfield, Rept. Geol. Surv. Ohio, vol. vii, pt. ii, pp. 483–4, 488, pl. xi, figs. 1–3; pl. xii, figs. 1–2.
1922. *Orbiculoidea meekana* Morningstar, Geol. Surv. Ohio, 4th ser., Bull. 25, pp. 171–2.

This species is one of the commonest fossils in the collection. From the Goniatite Bed twelve specimens were collected, while there are four from the junction of Sullana Road and Pariñas Quebrada, several in two small blocks from Steel Hill, Pariñas Quebrada and a small gully on its left bank, and six from Gramadal Quebrada. Those from the last-named locality are all very much compressed laterally, but there is no doubt as to their specific identity with the others. Most of the specimens are dorsal valves, but several ventral valves occur, and in one case the two valves are united.

Description.—Most of the valves are of moderate diameter, but one or two attain a relatively large size.

The dorsal valve is almost circular in outline and gently convex, except for a small concave area beneath the umbo. The latter is slightly curved and small, and is placed at a distance from the posterior margin equal to about one-third of the diameter. The height, too, is equal to about one-third of the diameter. In two specimens which, from the nature of the earlier formed shell, belong to this species, the height becomes equal to almost half the diameter and the umbo is more central—these seem to mark the limits of variation in these characters in the species. The surface is ornamented with numerous, closely-arranged, fine, concentric striae; where exfoliation of the shell has occurred, fine radial striation on the inner shell layers is shown, while internal casts may exhibit a somewhat coarser radial ornamentation.

The ventral valve is gently concave or nearly flat. The peduncle opening is placed slightly behind the low excentric apex, and appears to be small and oval. Specimens partly exfoliated show a shallow groove corresponding to the peduncle passage extending backwards from the peduncle opening, and nearly reaching the posterior margin. This valve is ornamented with fine growth-striae; where exfoliation has occurred, even only to a slight extent, the strength of alternate striae is increased considerably.

Remarks.—Derby (**2**, p. 494), records "two or more species" of "*Discina*" from Brazil, of which he states that one "is very similar to *D. missouriensis* Shumard". Katzer (**17**, p. 163) mentions them as *D.* cf. *missouriensis.* They may actually be identical with that species, but at any rate these statements give some help in making a comparison between the Peruvian and Amazonian faunas (*v. inf.*). Derby also records *Orbiculoidea* spp. in his other work on the Brazilian Carboniferous Brachiopoda (**62**, p. 60), but of these he stated that they are specifically indeterminate. The Peruvian form is quite distinct from *O. saltensis* Reed which occurs in Argentina (**27**, pp. 132–3, pl. xiii, fig. 1), since it lacks the small tubercles of that species, which also has a coarser ornamentation. But it compares very well with the description and figures given by Whitfield of the North American *O. meekana.*

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[1] For a later discussion of the validity of *Orbiculoidea* d'Orb., *vide* G. H. Girty, *Journ. Washington Acad. Sci.*, xviii, 5, 1928, pp. 128–42.

This species has generally been considered by American authors as synonymous with *O. missouriensis* Shum sp. (**28**, p. 221). The latter was not figured by Shumard, but he describes it as being small and as having parabolic growth-lines. The specimens figured as *Discina nitida* ? Phill. by Meek and Worthen (**77**, p. 572, pl. xxv, fig. 1), and those described as *D. nitida* Phill. both by White (**89**, p. 121, pl. xxv, fig. 10) and again by Keyes (**18**, p. 39, pl. xxxv, fig. 6) agree in size with Shumard's description and are now referred to *O. missouriensis* (Shum.). Similarly those figured as the latter species by Beede (**59**, p. 55, pl. viii, figs. 1–1*c*) are small. The larger size of his specimens and their concentric (and not parabolic) growth-lines were considered by Whitfield as of specific importance, and hence he separated them off from *O. missouriensis* as another species, *O. meekana.* This species has recently been considered by Morningstar (*loc. cit.*) as valid, and her conclusion seems justified. The Peruvian specimens differ in no important detail from the characterization given by Whitfield, and are hence referred to his species.

Localities.—Goniatite Bed, Pariñas Quebrada; junction of Sullana Road and Pariñas Quebrada; Steel Hill, Pariñas Quebrada; Gramadal Quebrada (east limb of fold), about 3 miles from its junction with the Pariñas Quebrada.

ARTICULATA.

PROTREMATA.

FAMILY PRODUCTIDAE.

Genus Chonetes Fischer von Waldheim.

Chonetes amazonicus Derby.

(Pl. XXIV, Figs. 13, 14.)

1874. *Chonetes amazonicus,* Derby, Bull. Cornell Univ. (Sci.), vol. i, No. 2, pp. 41–3, pl. vi, figs. 3, 12, 19; pl. ix, figs. 8, 9.

1892. *Chonetes amazonica,* Hall and Clarke, "Natural History of the State of New York, Palaeontology, vol. viii, An Introduction to the Study of the Genera of Palaeozoic Brachiopoda, pt. i," pl. xvB, fig. 13.

1903. *Chonetes amazonicus,* Katzer, "Grundzüge der Geologie des unteren Amazonasgebietes," p. 164, pl. vi, fig. 8.

In the Brachiopod Shales the commonest forms are remains of *Derbya tapajotensis* Derby and *Chonetes amazonicus* Derby. In addition several specimens of *Chonetes* occur at Gramadal Quebrada. These latter are always badly preserved, for in addition to limonitization of the shell they are partly rubbed. Their shape and size suggests *Ch. variolatus* d'Orb., though the sinus if present is very small and there is only a suggestion of ribbing. It is possible that some, if not all, are large specimens of Derby's species. Those from the Brachiopod Shales, however, belong quite definitely to *Ch. amazonicus.*

Description.—The shell is from small to medium in size, and subquadrate in outline. The length is equal to about from one-half to two-thirds of the width, which is greatest at or near the straight hinge-line. The ventral valve is of low inflation, and, though flattened about the axis, shows no median sinus. The umbo of the valve is small and inconspicuous. On either side of the umbo, and directed away from it, are six or seven short slender spines along the hinge-line, with which they make an angle of about 30°. The spines are continued as hollow tubes through the shell of the hinge, being directed towards the umbo in traversing the shell substance.

The exterior of the shell of this valve is known in one or two specimens. Its ornamentation consists only of a few faint concentric growth-lines. The interior is preserved in one case, while several internal casts occur. These show that a long thin septum extends from the umbo to beyond the centre of the shell, sometimes for as much as three-quarters of the length. On internal casts two narrow, elongated, slightly raised areas, one on either side of the furrow caused by the septum, correspond to the adductor impressions. The larger flabelliform diductor muscles leave well-marked raised areas round these—posteriorly each is marked by the area outside being suddenly depressed along a line running at about 30° to the hinge-line, but anteriorly the boundary is obscure. The inner surface of the valve is covered with small pustules arranged in radial lines, each pustule being inclined so that its maximum size is at its anterior end. Over the posterior three-quarters of the valve they progressively increase in size to the front, but near the anterior border the pustules appear to be all of the same dimensions.

The dorsal valve is not known definitely. Internal casts of one or two fragments appear to belong to it, however, and suggest a flattened valve which is internally pustulose like the ventral valve. A shallow but well-marked groove corresponds to the median septum which extends forwards for about half the length of the valve. On either side of this central groove and at an angle of about 30° with it is another shorter groove, while another symmetrically placed pair occurs outside of these near the hinge-line.

Remarks.—The specimens compare very well with those described by Derby from Brazil (*loc. cit.*). Kozlowski (**72**, p. 52), includes *Ch. amazonicus* Derby as a synonym of *Ch. glaber* Geinitz, but

Derby in his original description and comparison differentiated between the two species by the flatness of the ventral valve of *Ch. amazonicus*, its greater size, and the absence of a ventral sinus. To these differences may be added the longer median septum in the ventral valve. The depth of the sinus in any species of *Chonetes* is generally very variable, and in some the range of variation is such that at times the sinus may be completely or nearly absent. But when the absence of the sinus is always associated with a long median ventral septum, then those differences must be taken as constituting specific differences. Not only does Derby (*op. cit.*, pp. 43–5) mention the short septum in *Ch. glaber*,[1] but Meek (**21**, pp. 171–2) and Kozlowski (**72**, 52–5, pl. viii, fig. 13–15) also refer to it, and the latter's figures show it. The long ventral septum and the absence of a median sinus are features of the Peruvian specimens.

The species belongs to Davidson's *Laeves* group of *Chonetes* (**61**, p. 180), a group characterizing the Carboniferous and Permian. It differs considerably from *Ch. polita* M'Coy sp. (**61**, pp. 190–1, pl. xlvii, figs. 8–11; **75**, p. 456, pl. iiiD, figs. 30, 35), and from the five members of the group described by Waagen from the Salt Range (**29**, pp. 616 *et seq.*).

Locality.—Brachiopod Shales, Questa Colorado.

Chonetes variolatus (d'Orb.).

(Pl. XXIV, Fig. 15.)

1842. *Leptaena variolata*, d'Orbigny, "Voyage dans l'Amérique méridionale," T. iii, p. 49.
1842. *Productus variolata*, ibid., T. viii, pl. iv, figs. 10–11.
1902. *Chonetes variolata*, Tschernyschew, Mém. Com. Géol. St. Pétersbourg, T. xvi, pp. 597–600, pl. xxvii, figs. 9–11.
1914. *Chonetes variolatus*, Kozlowski, Ann. de Pal., T. ix, pp. 55, 56, pl. viii, fig. 16.
1914. *Chonetes variolatus*, Meyer, Neues Jahrb. für Min., etc., Beit. Bd. xxxvii, pp. 613, 633.

Two specimens definitely belonging to this species occur among the fossils from the Brachiopod Bed, but several others from Gramadal Quebrada may belong here (*v. sup.*).

Description.—The shell is medium in size and transverse, the greatest breadth, which occurs along the hinge-line, being equal to one and a half times the length. Both valves have a long and very narrow area, that of the dorsal valve being narrower than that of the ventral valve. The latter valve is convex but not very inflated. The umbo is small and not very conspicuous. Along the hinge-line occur at least six spines. The median sinus is very weak, while the side parts are not very much depressed. The ears are very small. Anterior to them the sides run almost straight for a short distance and then make a very broad curve into the anterior border. The dorsal valve is flat or slightly concave, but in plan has the same outline as the other valve. Both valves are ornamented with numerous low, fine, radiating ribs. Where exfoliation of the shell has occurred and the internal cast is exposed, numerous pittings arranged in radial rows indicate the pustulose nature of the inner surface.

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[1] It may be noted that although the species does not occur in his fauna, Meyer appears to accept *Ch. amazonicus* as a species distinct from *Ch. glaber* Gein., since he uses the former term in listing the Carboniferous Brachiopoda known from S. American areas other than the Amazonian region (**78**, p. 641).

Remarks.—In the shallowness of the median sinus the Peruvian forms differ from those mentioned and figured by d'Orbigny. But the specimen from the Amotape Mountains compares very well with one (B. 14233) in the Davidson Collection in the British Museum (Natural History), London, which appears from a note [1] accompanying it to be a syntype of d'Orbigny's species. It also compares well with those described by Kozlowski and by Meyer from Bolivia (*opp. sup. cit.*). The form referred to *Ch. granulifer* Owen by Cowper Reed (**27**, pp. 134–5, pl. xiv, fig. 6) is very similar, but the resemblance to the North American representatives of that species (**68**, pp. 654–63, pl. i–iv ; **12**, pp. 59–62, pl. vi, figs. 12, 13) is less than to d'Orbigny's. The Russian forms described by Tschernyschew (**86**, pp. 597–600, pl. xxvii, figs. 9–11) have deeper ventral sinuses, but in those figured by Mansuy from Indo-China (**74**, pp. 49–50, pl. iv, fig. 12), as well as in *Ch. variolatus* var. *baroghilensis* Reed from Chitral (**50**, pp. 40–1, pl. iii, figs. 1–4), the sinus is again shallow. The northward extension of the range of the species is shown by Toula's record of its occurrence in Barents Island (**85**, p. 554).

Locality.—Brachiopod Shales, Questa Colorado.

EXPLANATION OF PLATE XXIV.

All the figures are of the natural size, except where otherwise stated.

Fig.

1.—*Bellerophon* sp. cf. *crassus* Meek and Worthen. Posterior view. Brachiopod Shales, Questa Colorado.

1*a*.—Do. Side view.

2.—*Bucanopsis multiscalpta* sp. nov., holotype. Posterior view. Goniatite Bed, Pariñas Quebrada.

2*a*.—Do. Posterior view, × 2.

2*b*.—Do. Side view.

3.—Do. Side view of another specimen. Same locality.

3*a*.—Do. × 2.

4.—*Euphemus carbonarius* (Cox). Anterior view, × 2. Steel Hill, Pariñas Quebrada.

4*a*.—Do. Side view, × 2.

5.—*Euomphalus browni* sp. nov., holotype. Upper surface, × 1·5. Goniatite Bed, Pariñas Quebrada.

5*a*.—Do. Lower surface, × 1·5.

5*b*.—Do. Anterior view, × 1·5.

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[1] An extract from the note in Davidson's writing says : " *Chonetes variolata* d'Orb. . . . One of these examples was (*sic*) that marked II is one of d'Orbigny's original specimens of *C. variolata*."

Fig.

6.—*Pleurotomaria amotapensis* sp. nov., holotype. Apertural view, × 1·5. Goniatite Bed, Pariñas Quebrada.

6*a*.—Do. Posterior view, × 1·5.

7.—*Conularia* sp. aff. *crustula* White, × 2. Crinoid Beds, Pariñas Quebrada, east of Cerro Chaleco.

8.—Do. Another specimen, same locality.

9.—*Lingulidiscina* ? *sera* sp. nov., holotype. Dorsal view, showing impressions of the muscle-ridges on the internal mould where the shell is removed. Gramadal Quebrada (east limb of fold), about 3 miles from its junction with Pariñas Quebrada.

9*a*.—Do. Side View.

10.—Do. A crushed specimen showing the impressions of the muscle-ridges on the internal mould. Same locality.

11.—*Orbiculoidea meekana* Whitfield. A specimen retaining part of both valves. Ventral valve. Goniatite Bed, Pariñas Quebrada.

11*a*.—Do. Dorsal valve.

11*b*.—Do. Side view.

12.—Do. A well-preserved dorsal valve of another specimen. Same locality.

13.—*Chonetes amazonicus* Derby. A ventral valve. Brachiopod Shales, Questa Colorado.

14.—Do. Interior of another ventral valve, showing the internal septum. Same locality.

15.—*Ch. variolatus* (d'Orb.). A ventral valve, × 1·5. Same locality.

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(*To be continued.*)

Pleistocene and Recent Basalts of Transjordania and Palestine.

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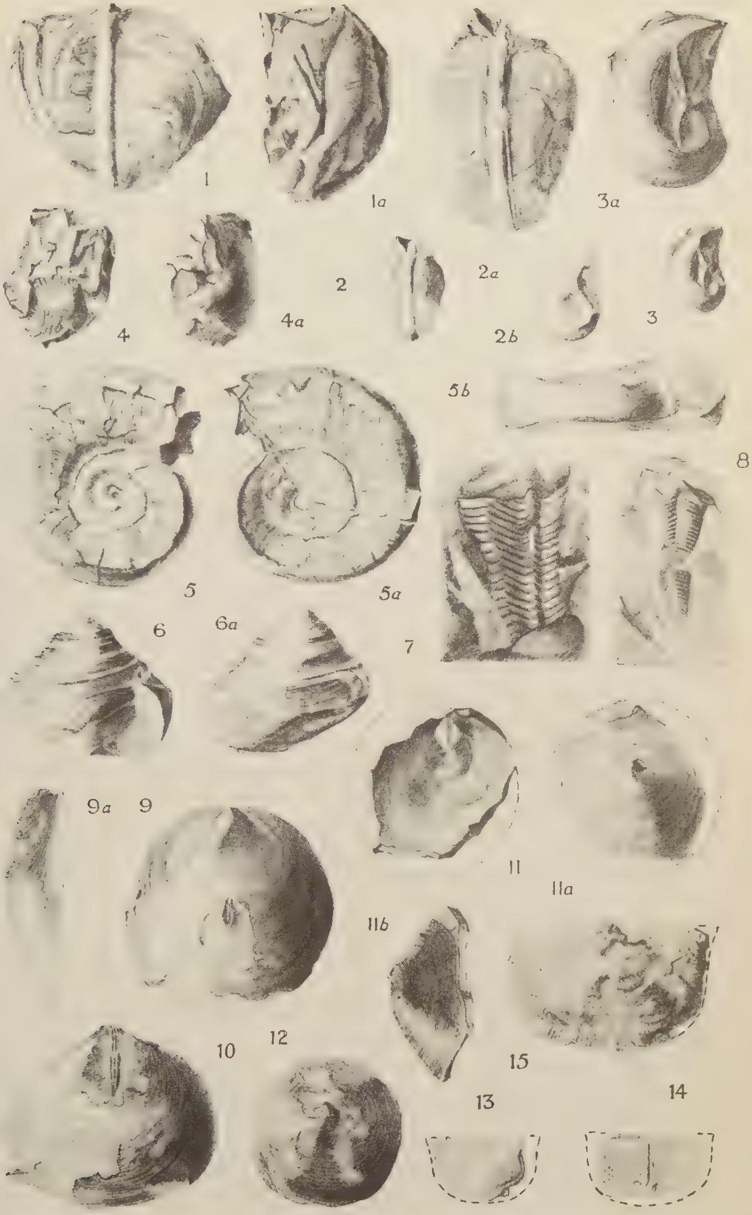
SYRABIA,[1] to use Krenkel's comprehensive term for the great region comprising Arabia, Syria, Palestine, and Sinai, has been the theatre of vast igneous activity from the Cretaceous to the present time. M. Blanckenhorn [2] divides the igneous rocks of this region into two groups, according to age, as Cretaceous-Eocene and Neogene-Quaternary. The Cretaceous-Eocene group includes

[1] E. Krenkel, *Geologie Afrikas*, Teil 1, 1925, p. 37.

[2] "Syrien, Arabien, und Mesopotamien," *Handb. Reg. Geol.*, Bd. v, Abth. 4, 1914, p. 42.



I.M.T. del.

PERUVIAN CARBONIFEROUS FOSSILS.

gabbro-serpentine-diabase intrusives and extrusives involved with, and restricted to, the Eurasian fold-mountain system in the northern part of the region, and also prevailingly basaltic eruptives occurring in the Syrabian plateau country.

The Neogene-Quaternary eruptives occur in north-western Arabia and the adjacent parts of Syria and Palestine, and form one of the most extensive recent volcanic regions of the world. They build the great Hauran plateau which stretches for 200 miles east of L. Tiberias. A western outlier of this basalt mass occurs to the south-west of L. Tiberias in the Plain of Esdraelon. Another almost equally large basaltic mass occurs in the extreme north on the boundaries of Syria, Mesopotamia, and Asia Minor. This sheet is covered by marine Upper Miocene beds. Other large basaltic outflows occur in western Arabia near the cities of Medina and Mecca. This later volcanic activity in Syrabia began in the Miocene, and continued almost to the present day, reaching its culmination in the Pliocene.[1]

The rock specimens on which this paper is based were collected by B. K. N. Wyllie, M.A., B.Sc., of the A.P.O.C., on the Amman-Ramadi road between Jerusalem and Baghdad, near the southern margin of the Hauran mass; and from near the Lake of Tiberias on its eastern shores. Blanckenhorn states that the enormous volcanic accumulations which cover the region stretching from Damascus on the north, through the Djōlān, Hauran, and Dirêt el-Tulūl, coincide in time with the gaping of the Syrian fracture system in the Early Quaternary.[2] The volcanic activity continued, however, well into the Middle Pleistocene. One of the youngest lavas from the Djōlān flowed down and filled the already-eroded Jarmuk valley to near its junction with the Jordan. This region is the biblical Land of Bashan. Still later outbreaks gave rise to the wild and well-preserved volcanic region of es-Safa near Damascus, in which the activity may have continued into historical times, as according to some interpreters of Holy Writ volcanic eruptions took place in and around Palestine in the times of King David. An excellent popular account of the Arabian and Syrian volcanic region is given by E. Hull.[3]

Through the kind offices of Mr. W. Campbell Smith, the writer has been privileged to see, and permitted to describe, a small collection of thin sections of basaltic rocks collected in Palestine and Transjordania, and belonging to the British Museum (Natural History). These include rocks intrusive into Trias and Cretaceous, presumably belonging to the earlier period of igneous activity in this region, along with others belonging to Plio-Pleistocene and

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[1] E. Krenkel, op. cit., *supra*, pp. 76–7.

[2] Op. cit., pp. 44–5. See also P. Range, *Die Isthmuswüste und Palästina.* Die Kriegschauplätze, 1914–18, geologisch dargestellt. Heft 14, 1926, pp. 62–3.

[3] *Volcanoes Past and Present*, 1892, pp. 126–35.

Recent eruptions, which are germane to the subject of the present paper.

Petrography.—The first important petrographical investigation of Syrian basalts was that of B. Doss,[1] who showed that the Pleistocene and Recent lavas of the Hauran were "plagioclase-basalts", "anamesites", and dolerites, often with abundant porphyritic olivine and purple augite. Many of the rocks are rich in apatite, and a few contain abundant flakes of biotite in their groundmass. One rock was a "hornblende-basalt" with a porphyritic red-brown amphibole. These rocks are trachybasalts; they are thoroughly undersaturated, and have a clear alkaline tendency, although Doss reported no felspathoids.

In 1896 W. Potz[2] described the basaltic rocks of the region between the Gulf of Alexandretta and Homs, and inland to the headwaters of the Euphrates, in North Syria. These eruptions prove to be plagioclase-basalts similar to those described by Doss from more southerly regions. They are porphyritic with labradorite and olivine, and often rich in the latter mineral. Three examples of nepheline-bearing felspar-basalts or basanite were described, in which the nepheline was determined by micro-chemical means. These basalts range from Miocene to Pleistocene in age.

In 1916 E. Fuchs[3] described Cretaceous, Pliocene, and Pleistocene basalts from the neighbourhood of Lake Tiberias, the Dead Sea, and from the southern stretch of the Hedjaz Railway between the Dead Sea and Medina. The Pliocene and Pleistocene basalts from all the described localities are, in the main, rich in porphyritic olivine and purple augite.

The latest investigation of Palestinian basalts, by N. Shalem,[4] provides microscopic descriptions of a Cretaceous basalt from Samaria, two Pleistocene olivine-basalts from the Plain of Esdraelon with an analysis, and a doleritic inclusion in one of the latter rocks with an analysis. The petrographic descriptions are at variance with the analyses given (see p. 414).

The Palestinian basalts collected by Mr. B. K. N. Wyllie are fine-grained, grey, porous rocks in which inconspicuous phenocrysts of olivine and occasionally augite may be found. A rock from Wadi Shakeiyif, near the eastern shore of L. Tiberias (H.M., R. 4659),[5] shows numerous phenocrysts of olivine in a groundmass consisting of labradorite, augite, olivine, and iron ores. The olivines are worn and corroded, but still retain traces of crystal outlines. They often have a central or marginal alteration to an orange-coloured serpentine. Occasionally this alteration is restricted to a narrow zone near the margins of the crystal, and is surrounded by a peripheral zone of perfectly fresh olivine, suggesting that the alteration took place in the magmatic stage. The groundmass is fine-grained but holocrystalline, showing an intergranular texture made up of slender laths of labradorite fluidally arranged, with subhedral grains of pale purple augite, olivine, and iron ores. This rock has been analysed (p. 413).

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[1] "Die basaltischen Laven und Tuffe der Provinz Hauran und vom Dirêt el-Tulūl in Syrien," *Tscherm. Min. Mitth.*, vii, 1886, pp. 461–533.

[2] "Beiträge zur Kenntniss der basaltischen Gesteine von Nord-Syrien," *Zeitschr. d. Deutsch. Geol. Ges.*, xlviii, 1896, pp. 522–56.

[3] E. Fuchs, "Beiträge zur Petrographie Palästinas und der Hedschasprovinz," *N.J. f. Min.*, B.-B. xl, 1916, pp. 533–82.

[4] "Sopra alcuni Basalti della Palestina," *Boll. Soc. Geol. Ital.*, xlvi, 1927, pp. 51–65.

[5] "H.M." refers to specimens in the Hunterian Museum, University of Glasgow; "B.M." to specimens in the British Museum, Natural History.

The British Museum specimen from this locality (B.M., 1924, 1037 (95)) is, however, almost identical with the Zeizun rock described below, except that the olivine phenocrysts are enclosed in a more continuous ophitic plexus, and are somewhat serpentinized. Iron ore, too, is slightly more abundant.

The Recent flow in the Jarmuk valley at Zeizun, on the railway about 20 miles east of L. Tiberias, is a dark-grey, fresh, porous basalt (B.M., 1924, 1037 (90)). In thin section it shows numerous phenocrysts and glomeroporphyritic groups of fresh olivine, and plates of purple augite in ophitic relations with labradorite, in a coarse, intergranular groundmass consisting of narrow, elongated laths of labradorite, granules of olivine, augite, and iron ores. There is also a scanty cryptocrystalline or glassy base. A few tiny flakes of red-brown biotite and some needles of apatite can also be identified. The large plates of titanaugite which ophitically enclose felspar laths are separated by spaces in which augite is only sparsely developed or is absent. The plagioclase microlites are slightly zonal and give extinctions indicating a composition about Ab_1An_1. This rock has been analysed (p. 413).

A rock from Jisr Mejamie, east of the Jordan about 6 miles south of L. Tiberias (B.M., 1924, 1037(92)), contains numerous phenocrysts of fresh olivine in a coarse, intergranular groundmass consisting of elongated laths of labradorite, granules of pale augite, and irregular patches of ilmenite. A rough, sheaf-like arrangement of the felspar laths is shown and there is an occasional larger crystal, or group of crystals, of the felspar. A fibrous, green, serpentinous mineral has migrated into the numerous pores.

From the Wadi el Arab, also to the south of L. Tiberias (H.M., R. 4658), comes a basalt very similar to that of the Wadi Shakiyif, but of much coarser grain.

A rock from El Kuneitra, on the Acre-Damascus road about 20 miles north-east of L. Tiberias (B.M., 1924, 1037 (91)), is practically identical with that from the Jisr Mejamie, but is somewhat fresher. The phenocrystic olivines are rimmed with orange serpentine, and there are a few phenocrysts, or glomeroporphyritic groups, of augite.

The British Museum collection contains two Recent basalts from localities near the Dead Sea. That from Wadi Fiddah (B.M., 1924, 1037 (81)) differs little from those described above. More felspar is involved in the intergranular groundmass than in the type-rock from Wadi Shakeiyif. There are also large glomero-porphyritic groups of augite poikilitically enclosing some orange-rimmed olivine crystals.

A rock from Dat Ras, about 8 miles east-south-east of the southern shore of the Dead Sea (B.M., 1924, 1037 (80)), contains numerous small, orange-spotted olivine phenocrysts in a very fine-grained, intergranular groundmass, in which granules of colourless augite and magnetite decidedly predominate over the felspars. A colourless isotropic mineral in the groundmass may be analcite, and there is perhaps a little nepheline.

The four basaltic rock specimens collected by Mr. B. K. N. Wyllie on the southern edge of the Hauran plateau near the Jebel Douz, about 200 miles east of Amman, are all very much alike (H.M., R. 2400–3). They are dark-grey, porous basalts which, in thin section, shows numbers of small olivine phenocrysts, or micro-phenocrysts, in an intergranular groundmass consisting of labradorite, purple augite, olivine, and iron ores. Both in composition and texture these rocks closely resemble the Dalmeny basalt type of the Scottish Carboniferous.[1] The groundmass varies only in grain size ; and in the more fine-grained types the felspars tend to exhibit a fluidal arrangement. In one of the rocks (H.M., R. 2401) the felspar laths are much broader than usual and have a markedly zonal structure. As the open spaces in these rocks are filled with calcite owing to a phenomenon of infiltration described later, it was not deemed advisable to have a chemical analysis of this type ; but it differs from the analysed rocks only in containing smaller, but more numerous, olivine phenocrysts, and is probably of almost identical chemical composition.

Chemical Composition.—Analyses of two basaltic lavas from localities east of the Lake of Tiberias have been made by Messrs. W. H. and F. Herdsman with the results set out in Table I, 1 and 2. With these are tabulated analyses of basalt and dolerite from the Plain of Esdraelon (3 and 4) published by N. Shalem, and an analysis of a Miocene basalt dyke from eastern Egypt.

Notwithstanding the difference of 4 per cent in the silica of the two Transjordanian basalts, the rocks are closely similar, as will be seen from the norms tabulated in Table II, 1 and 2. Both rocks contain more than 20 per cent of olivine, and in both cases the norms show a small amount of nepheline. Hence these basalts are thoroughly undersaturated and possess a slight alkaline tendency.

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[1] A. G. MacGregor, "The Classification of Scottish Carboniferous Olivine-basalts and Mugearites," *Trans. Geol. Soc. Glasgow*, xviii, pt. ii, 1928, pp. 324–60.

TABLE I.

	1	2	3	4	5
SiO_2	41·45	45·50	43·86	50·51	50·1
Al_2O_3	17·73	17·73	16·25	19·11	17·7
Fe_2O_3	2·26	1·71	7·44	9·36	·65
FeO	9·22	9·07	3·46	·59	7·85
MgO	9·76	9·59	5·49	1·33	5·0
CaO	10·64	9·64	10·46	5·97	10·0
Na_2O	2·45	2·67	2·32	3·92	3·5
K_2O	·87	·85	3·24	5·08	1·3
$H_2O +$	·80	·98	·89	·87	Ign. 1·4
$H_2O -$	1·30	·32	·88	1·64	
TiO_2	2·40	1·80	4·10	tr.	2·4
P_2O_5	·96	·26	1·00	—	—
MnO	tr.	tr.	tr.	2·26	—
S	*nil*	*nil*	—	—	—
CO_2	*nil*	*nil*	—	—	—
	99·84	100·12	99·39	100·64	99·9

1. Olivine-basalt (? Pleistocene), Wadi Shakeiyif, L. Tiberias, Transjordania. Anal. W. H. and F. Herdsman.
2. Olivine-basalt (Recent), lava flow, Zeizun, Jarmuk Valley, Transjordania. Anal. W. H. and F. Herdsman.
3. Olivine-basalt (Pleistocene), Nahalal, Plain of Esdraelon, Palestine. Anal. N. Shalem (?). Quoted from N. Shalem, *Boll. Geol. Soc. Ital.*, xlvi, 1927, p. 60.
4. Doleritic inclusion in olivine-basalt lava (Pleistocene), Giv'at el Hamorè, Plain of Esdraelon, Palestine. Anal. N. Shalem (?). Quoted from N. Shalem, ibid., p. 64.
5. " Mediterranean " basalt (Miocene), dike, Khéchen, east of Cairo, Egypt. Quoted from J. Barthou, " Chronologie et Description des roches ignées du desert arabique," *Mem. Inst. Egypte*, tom. v, 1922, p. 231.

TABLE II.

	1	2	3	4	5
Orthoclase	5·0	5·0	18·9	30·0	7·8
Albite	10·0	18·9	12·3	23·6	28·8
Anorthite	35·0	33·9	24·7	19·5	28·9
Nepheline	5·7	2·0	3·8	5·1	·3
Diopside	9·9	9·7	16·2	7·8	17·1
Olivine	22·1	22·8	4·3	—	10·3
Magnetite	3·2	2·5	—	9·3	·9
Ilmenite	4·6	3·5	7·3	—	4·6
Haematite	—	—	7·4	2·9	—
Rutile	—	—	·2	—	—
Apatite	2·0	·7	2·3	—	—

Order of analyses the same as in Table I. The symbols of the analyses in the C.I.P.W. classification are as follows :—

1.	″III	5 (6)	4	4″
2.	II (III)	5	4	4″
3.	(II) III	5″	3	3
4.	″II	5″	2 (3)	3
5.	II″	5	3 (4)	4

Reckoning orthoclase in with albite, the normative compositions of the plagioclases in the Wadi Shakeiyif (Table II, 1), and Zeizun

(Table II, 2), basalts are $Ab_{30}An_{70}$ and $Ab_{41}An_{59}$ respectively, which agree fairly closely with the actual compositions as determined by optical methods. Doss gives two analyses of felspars separated from Hauran basalts[1] which, when computed in the same way as above, give respectively $Ab_{32}An_{68}$ and $Ab_{29}An_{71}$.

Shalem's analyses of olivine-basalt and "dolerite" from the Plain of Esdraelon differ materially from those above-described, principally in the amounts of potash, which are much greater than those contained in the other analysed basalts from the region. A reference to the table of norms will show that this means there must be from 20 to 30 per cent of orthoclase present in these rocks, an amount which could not possibly have escaped notice in the microscopical investigation. Shalem, however, does not mention orthoclase in his descriptions; neither has this mineral been observed by any previous investigator of Palestinian, Syrian, and Transjordanian basalts. It is certainly not present in any significant quantity in any of the rocks described in this paper. While it would be unwise to deny the possible occurrence of orthoclase-basalts or shoshonites in Palestine, the discrepancies between Shalem's analyses and the accompanying petrographical descriptions of the rocks would seem rather to throw doubt either upon the accuracy of the analyses or on the microscopical work. The view that the analyses are at fault is supported by other peculiarities, notably the amounts of ferric oxide recorded when the rocks are not stated to be altered to a sufficient extent to provide these amounts, and the extraordinary record of 2·26 per cent of manganous oxide in the "doleritic inclusion" (Table I, 4). Again, while the unusual quantity of 4·10 per cent of titanium dioxide is recorded in one rock, there is only a trace of this constituent in the other. The only conclusion that the writer can come to is that these analyses are quite unreliable.

The chemical composition of the basalt belonging to the Miocene "Mediterranean" suite, described by J. Barthou, from eastern Egypt, corresponds fairly well with that of the Transjordanian basalts of a later period. While the silica is higher, olivine still appears in the norm although in reduced amount, and there is still a deficiency in silica sufficient to produce a minute amount of nepheline (Table II, 5).

CALCAREOUS CRUSTS ON THE HAURAN BASALTS.

Calcareous infiltrations into the Hauran basalts have already been mentioned They fill irregular, drusy cavities in the porous basalts. Crystals of felspar and augite with perfectly euhedral outlines project into the filling and the carbonate occasionally surrounds apparently detached crystals. There is not the slightest trace of alteration in the rocks, and it is abundantly clear that the carbonate fillings have not been derived from the basalts, but from outside sources.

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[1] Op. cit., p. 477.

These infiltrations can be seen to stand in close connection with calcareous crusts on the surfaces of the basalts, and with what Mr. B. K. N. Wyllie in a letter says are " sub-surface, concretionary, calcareous growths which seem to help in disrupting surface rocks, but end by glueing them together again ". These crusts and more irregular growths are firmly welded to the surfaces of the basalts. In thin section they show stalagmitic or onyx-like, wavy, banded layers of brown, turbid calcite, enclosing a few, scattered, angular grains of quartz and felspars, and a few crystals of olivine and augite obviously detached from the basalts. A larger hand specimen from a thick crust shows beautifully-developed, large and small pisoliths, embedded in a coarsely-crystalline calcite base again containing scattered crystals of quartz and felspar. Still another specimen has been extensively silicified.

These calcareous crusts appear to be common in arid and desert regions.[1] Their materials, at least in the Hauran region, have not been derived from the basalts. To the writer it appears probable that their source is to be found in the calcareous dust and sand of the Syrian Desert derived from the extensive outcrops of Cretaceous and Kainozoic limestones. Dew and infrequent rains may cause the solution of a portion of this material, the subsequent rapid evaporation of the solutions then leading to deposition of calcite within the pores and steam-cavities of the basalts, and also as thin layers on the surfaces of the rocks. Repeated re-solution and re-deposition would lead in some places to the development of pisoliths, and ultimately to the formation of thick calcareous crusts.

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Limestone and the Origin of Felspathoidal Rocks: an Aftermath of the Geological Congress.

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> " The alkaline group of igneous rocks seems to offer a specially valuable test of any petrogenic theory."—R. A. DALY.

IF there is one branch of geology that was more strongly represented than another at the Fifteenth International Geological Congress in Pretoria, it is petrology. It is true that the petrologists did not present many papers, and that their official discussions were rather scamped, but it was on the excursions that they showed their real strength. I shall not soon forget the day when I conducted a party of fifty to Pilansberg. To see them jump from the buses at every stop; to hear fifty hammers ringing at once on my favourite nepheline rocks; to see the collecting bags swelling and the buses sinking lower and lower on their springs; few sights have ever given me keener pleasure. The Franspoort-Leeuwfontein excursion was also a purely petrological occasion, in which more than fifty took part; and then at the end of the Congress some thirty of us enjoyed ten days of concentrated petrology on the Bushveld excursion, under the inspiring leadership of A. L. Hall.

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[1] S. Passarge, " Die geologische Wirkung des Windes," *Grundzüge der Geologie*, 1924, p. 658.

By day, as we trundled along in the buses; in the evening, in hotels and in the quaint quarters we occupied on the Bushveld excursion; there were countless opportunities for discussion. The differentiation of the norite, the origin of the chromite seams, crystal settling, and the genesis of alkaline rocks are only a few of the problems that cropped up. It is of the last-mentioned that I wish to speak. In a congress which included Bowen, Quensel, Niggli, Hall, Scheumann, Morozewicz, T. L. Walker, Reuning, Grout, and many more who have had first-hand experience of alkaline rocks in the field, the opportunity of comparing notes on my favourite subject was too good to be missed. The climax was reached one night at Magnet Heights, when Bateman challenged us on the question of limestone-assimilation. There was a spirited discussion in which nobody succeeded in convincing anybody else—indeed, Harrison summed the discussion up in a well-known quatrain from Omar Khayyam—but I was left with a definite impression that the opponents of Daly's hypothesis have scarcely appreciated the cumulative strength of the evidence in its favour. I resolved that when I got back to pen and paper I would make one more attempt to state that evidence, and at the same time to discuss the alternative hypotheses which have been born in the last half-dozen years.

The hypothesis of the origin of felspathoidal rocks by reaction between magma and limestone was first set down in black and white by R. A. Daly in 1910 and repeated and elaborated by him in 1914 and 1918. Very likely the idea had occurred to others before him; I know, for instance, that Horne and Teall gave it some thought at Loch Borolan in 1892. It was my own work in that area previous to 1910 that prepared my mind for the acceptance of Daly's theory and has inclined me towards it ever since.

Critics of Daly's hypothesis have too often confined their attention to a single aspect of it, namely the simple solution of lime in basaltic or granitic magma, forgetting that Daly's statement of the matter indicates the operation of three distinct factors, as follows:—

(1) Solution of limestone by magma, leading to direct formation of felspathoids by desilication of felspar molecules;

(2) Sinking of heavy lime-silicates and complementary rise of a light alkaline fraction under control of gravity;

(3) Formation of alkaline carbonates and rise of these towards roof of magma chamber, where carbon dioxide is displaced by silica.

The operation of the *first* of these factors can be studied in the field; I shall return to it presently. The *second* factor is just the familiar process of gravitational differentiation which has been demonstrated both in the field and in the laboratory; I shall say no more about it, because it is a process that is not peculiar to alkaline magmas. The operation of the *third* factor cannot be studied in the field on account of the disappearance of carbonic acid from the system, yet it is of much importance to the theory, for it provides an alternative method by which nepheline and other soda-rich minerals may be formed in the magma. Daly even suggested that perhaps " it is the presence of carbon dioxide rather than of dissolved carbonate in subalkaline magma which is the principal condition for the differentiation of fractions rich in alkalies ".

Either sodium carbonate or sodium silicate may be generated by reaction between albite and calcium carbonate if an aluminosilicate of lime is formed at the same time. In the following equations it is assumed that a lime-garnet is formed.

$$2\,NaAlSi_3O_8 + 5\,CaCO_3 = Na_2SiO_3 + Ca_3Al_2Si_3O_{12} + 2\,CaSiO_3 + 5\,CO_2$$

$$2\,NaAlSi_3O_8 + 6\,CaCO_3 = Na_2CO_3 + Ca_3Al_2Si_3O_{12} + 3\,CaSiO_3 + 5\,CO_2$$

That such compounds as sodium carbonate and sodium metasilicate are actually generated in alkaline magmas is shown by the presence of cancrinite, pectolite, and other uncommon soda-rich minerals in many nepheline rocks. These light and very soluble sodium salts must tend to rise, together with juvenile and resurgent fluids, towards the top of the magma-chamber. In doing so they may react with albite and anorthite molecules to give a further supply of nepheline, as follows :—

$$NaAlSi_3O_8 + 2\,Na_2CO_3 = NaAlSiO_4 + 2\,Na_2SiO_3 + 2\,CO_2$$

$$CaAl_2Si_2O_8 + Na_2SiO_3 = 2\,NaAlSiO_4 + CaSiO_3$$

and even, when the temperature falls low enough,

$$CaAl_2Si_2O_8 + Na_2CO_3 = 2\,NaAlSiO_4 + CaCO_3.$$

Now although this discussion lacks a sufficient experimental or observational basis, it points to a very important conclusion, namely that under the operation of factors (2) and (3) *a body of highly alkaline rock may be formed at a distance from any visible body of carbonate rock*. Thus the absence of limestone from the immediate neighbourhood of a felspathoidal rock cannot be regarded as proof that limestone played no part in its formation.

In discussing his hypothesis Daly has generally assumed that the reacting magma was basaltic, although he states that " more acid magma is also sensitive to the solution of carbonate ". To convert an ordinary basalt containing, let us say, 20 per cent of albite molecules into a nepheline-tephrite containing 5 per cent of albite and 8 per cent of nepheline, there would be needed a mass of calcium carbonate equal to about 12 per cent of the weight of the basalt. I find that many petrologists are prepared to grant the possibility of reaction on this limited scale and will allow that tephrites, basanites, and felspathoid-basalts may have been formed by Daly's reaction. The recent discovery by C. E. Tilley of nepheline in the contact zone of a basaltic intrusion in Chalk in Ireland, and the still more striking discovery by H. A. Brouwer of limestone blocks containing veins of leucite-phonolite in an andesitic volcano in Java, should remove any doubts that remain on this point.

Among deep-seated rocks, however, the commonest felspathoidal type is not a theralite (which might be regarded as a slightly desilicated gabbro) but a foyaite, which has the composition of a desilicated granite or syenite. Now although no new principle is involved, the desilication of a granite is a much more serious problem than that of a basalt, for the amount of silica to be removed is so much greater. To neutralize 100 parts of silica, 167 parts of calcium carbonate must be supplied. Beyond this, every 100 parts of albite that are reduced to nepheline require 76 parts of limestone, and every 100 parts of orthoclase that are reduced to kaliophilite require 71 parts of limestone.

Consider a granite containing 30 per cent of quartz, 30 per cent of orthoclase, 30 per cent of albite, and 10 per cent of mica and accessories, and suppose it to be converted into a foyaite in which (say) one-third of the total felspar is replaced by nepheline. Then

30 parts of quartz require 50 parts of $CaCO_3$
16 parts of albite require 12 parts of $CaCO_3$ to give 9 parts $NaAlSiO_4$
4 parts of orthoclase ,, 3 ,, ,, ,, 2 ,, $KAlSiO_4$

65 ,, ,, ,, 11 ,, nepheline

If we assume for the sake of simplicity that no lime silicates appear in the final product, in consequence of the sinking of heavy molecules, then the resulting foyaite will consist of 43 per cent of orthoclase, 23 per cent of albite, 18 per cent of nepheline, and 16 per cent of mica and accessories, and it will have about 60 per cent of the bulk of the original granite. If some of the lime minerals are retained in the foyaite, the bulk of the latter will be so much greater. Briefly then, 100 parts of granite of the reasonable composition stated above will require to react with 65 parts of limestone in order to give from 60 to 80 parts of foyaite.

Can a hundred parts of granitic magma supply sufficient heat to dissolve 65 parts of limestone? Certainly not, but perhaps a thousand parts or ten thousand parts can. It is necessary to remember that in a large number of well-investigated cases, foyaite bodies are just local facies of vastly greater bodies of granite or some other sub-alkaline rock, and that the temperature of the smaller mass may be maintained by the larger mass, in which case the difficulty of heat-supply simply does not arise. For instance, according to W. C. Brögger the eruptive rocks of the Kristiania district have a volume of 2,377 cubic kilometres, of which foyaite composes only 7 cubic kilometres or 0·29 per cent. H. S. Washington has estimated that the complex of Essex Co., Massachusetts, contains 63·6 per cent of granite, 33·4 per cent of diorite, and only 0·8 per cent of foyaite and essexite. In the Haliburton-Bancroft district of Ontario the granites cover 2,600 square miles, the foyaites only some 15 square miles, and W. G. Foye says that the total mass of the foyaites is " far less than one per cent of the total mass of the granites ". In the Transvaal, in spite of the fact that Pilansberg is one of the biggest masses of nepheline rocks in the world, the total area covered by felspathoidal rocks is less than 200 square miles, as contrasted with the 37,000 square miles of the great Bushveld complex as a whole. The volume relation in this case is perhaps no greater than 1 : 1,000. According to P. Chirvinsky the areal proportions in the Ilmen Mountains are granite 74·6, syenite 7·2, foyaite (miaskite) 16·2.

I argue, then, that there is no theoretical objection to the proposition that a *large* body even of granitic magma may give rise to a *much smaller* body of felspathoidal magma by reaction with limestone. Since the foyaitic magma has a very low temperature of consolidation it will tend to be expelled into contraction-fissures or faults in the main mass of rock, or to be driven by escaping gases towards volcanic vents in the roof; thus there may be a concentration within a limited area of foyaitic magma which originated throughout a much wider area. For instance, in the case of the Bushveld complex, the foyaite which appears at the great volcanic centre of Pilansberg, in the smaller pipes of the Franspoort volcanic line, in the Sekukuniland stock, and in the big dykes of the Rustenburg district may have been generated throughout a wide area in the sub-floor of the complex and concentrated by way of fault-planes and diatremes. In my recent work on Pilansberg I expressed the matter as follows:—

" I conceive that after the emplacement of the norite and the red granite there was an unconsolidated residue of granitic magma trapped in the depths, about the base of the Transvaal system; that this residual magma, rich in fugitive constituents as granitic residues always are, reacted with the thick limestones at the base of the system, giving rise to local accumulations of highly alkaline magma; and that the development of faults across the main complex gave an opportunity for this differentiated magma to ascend, forming dykes, plugs, and sheets."

If it be granted then that there is no theoretical objection to Daly's hypothesis, provided that the mass of the product is small in comparison with that of the parent magma, then those who refuse to accept the hypothesis must base their objection on some supposed inadequacy of the field evidence. But is the field evidence inadequate? If one shows that there is no theoretical objection to a geological hypothesis, and that it is upheld in some instances by direct evidence and in many others by circumstantial evidence, is not that hypothesis as well based as one has any reason to expect?

What may reasonably be demanded in the way of proof? That every intrusion in limestone shall show a marginal facies of felspathoidal rock? Surely not, because the reaction is controlled by three highly variable factors, namely temperature, pressure, and gas-concentration, and perhaps by geological structure, too; and also because a reaction that involves the liberation of carbon dioxide must be accompanied by strong convection currents in the liquid, which will tend to sweep the products of reaction away from the place where they were formed. In some cases there may be no reaction at all; in others, sodium carbonate or sodium silicate may be formed and carried away in solution; in others, a felspathoid may be generated as a temporary phase which is afterwards reabsorbed by the magma; and in other cases still the desilicated magma may be swept away from the contact region, to form an apparently later intrusion at a distance from the place where it was generated. It must not be forgotten that the contacts which we see to-day tell only part of the story; other chapters have been removed by erosion, or they may still await exposure. The absence of felspathoids from some limestone contacts, then, is without significance in comparison with their presence at others.

It seems to me that all we can reasonably expect, taking into consideration the imperfect nature of geological evidence in general, is that

(*a*) *most* occurrences of felspathoidal rocks should be in regions where there is known to be a strong development of limestone; and

(*b*) *in some* cases there should be clear evidence of reaction between magma and limestone with production of felspathoids.

(*a*) Daly dealt very fully with this point. In 1914 he gave a list of 234 localities where alkaline eruptives are developed, and showed that in 163 of these localities limestone is present among the rocks cut by the eruptives; in 63 more there is insufficient evidence regarding the country rocks; and in only eight cases are the geological conditions such that assimilation of limestone seems to be impossible. That is, of 171 occurrences which permit the nature of the country rock to be observed, 95 per cent are in regions where limestone is present. The most striking point in this demonstration is the number of *large intrusive bodies* of foyaite and related rocks which cut thick limestone formations. I have tabulated many such bodies below under the heading "favourable", adding a few that are not in Daly's table. A second list, headed "indecisive", includes cases where there is either too little information about the nature of the country rocks or else limestone is present but its quantity or its relation to the eruptives is not known. The "unfavourable" instances in the third table are intrusive in granite, gneiss, schists, or sediments other than limestone; but in six of the nine cases the evidence regarding the nature of the country rocks is very meagre.

Favourable.

Haliburton-Bancroft (23 cases)
Monteregian Hills (5 cases)
Ice River, B.C.
Franklin Camp, B.C.
Kruger Mountain, B.C.
Magnet Cove, Ark.
Fourche Mountain, Ark.
Saline County, Ark.
Potash Sulphur Springs, Ark.
Beemerville, New Jersey
Libby, Montana
Tamaulipas, Mexico
Jacupiranga, Brazil
Costa Rica
Nyassaland
Loch Borolan, Scotland
Kristiania district
Fen district, Norway
Alnö, Sweden
Pouzac, Pyrenees
Ditro, Transylvania
Miask, Urals
Zarafshan, Turkestan
Yenisei district, Siberia
Botogol Hill, Siberia
Sviatoy Noss, Transbaikalia
Madagascar
Bushveld complex (7 cases)
Palabora, Transvaal

(Total, 61.)

Indecisive.

Cabo Frio, Brazil
Sao Paulo, Brazil
*Cevadaes, Portugal
*Monchique, Portugal
Mariupol, Russia
Coimbatore, India
Kishengarh, India
*Granitberg, S.W. Africa
*East Africa
*Tasmania
Shansi, China
*Seiland, Norway
*Kuolajärvi, Finland
Hassi Aussert, W. Africa
*Sundance, Wyoming
*Uncompahgre, Colorado

(Total, 16.) (* Means limestone present.)

Unfavourable.

Umptek, Kola
Lujaur-Urt, Kola
Turja, Kola
Kuusamo, Finland
Almunge, Sweden
Julianehaab, Greenland
Port Coldwell, Ontario
Poohbah Lake, Ontario
Red Hill, Mass.

(Total, 9.)

Further consideration of these apparently unfavourable instances is deferred for the moment.

(*b*) Among localities where there is clear evidence of desilication of magma by limestone, the following examples are outstanding :—

Tory Hill, Ontario
Mount Royal, Quebec
Oka Hills, Quebec
Ice River, B.C.
Magnet Cove, Ark.
Jacupiranga, Brazil
Loch Borolan, Scotland
Fen district, Norway
Alnö, Sweden
Kuolajärvi, Finland
Sviatoy Noss, Transbaikalia
Botogol Hill, Siberia
Granitberg, S.W. Africa
Sekukuniland, Transvaal
Palabora, Transvaal

To go into details would require too much space. I shall just say that in most of these instances the actual contact between alkaline rock and massive limestone is exposed to view and there is clear evidence of desilication of the magma and its enrichment with lime. Close to the contact, ijolitic, shonkinitic, and jucupirangitic or pyroxenitic rocks are developed which contain large quantities of diopside-hedenbergite together with other lime minerals such as cancrinite, melanite, calcite, sphene, apatite, pectolite, and sometimes melilite or scapolite.

In these instances, and as far as the genesis of the ijolitic, shonkinitic, jacupirangitic and pyroxenitic facies is concerned, Daly's case is proved.

But, the critics say, this does not prove that the much more common and abundant foyaites, which are typically poor in lime, were formed by the same reaction. The criticism is just, and I do not wish to minimize its importance. I have myself shown that in Sekukuniland the ijolite is clearly a product of reaction between foyaite and limestone, but that there is no evidence of how the foyaite originated. The fact is that in this matter one comes up against the limitations of geological evidence. It is an essential feature of Daly's hypothesis that reaction with limestone is followed by the separation, in a vertical direction, of a lighter alkali-rich fraction from a heavier lime-rich fraction. That being so, the genesis of the lighter fraction can only be studied properly in a vertical section, which in the case of the Sekukuniland stock might require to be three miles deep!

There is another unavoidable weakness in our demonstration, upon which C. H. Smyth has laid his finger. He claims, with special reference to the Sekukuniland stock, that " the magma is not alkaline because it has assimilated limestone, but it assimilates limestone because it is alkaline and therefore has a high concentration of volatile constituents, great liquidity, and strong pressure ". For the reason already given it is impossible to decide, in the field, between Smyth's interpretation and mine. But if Smyth's view is accepted we are left without any explanation of the origin of the foyaite of Sekukuniland, although the associated ijolite is unquestionably due to Daly's reaction; that is, we find ourselves in the curious position of being able to explain the origin of the more highly undersaturated rock but not that of the less highly undersaturated one. Is it not more reasonable to suppose that the same cause operated in both instances, but that some parts of the magma suffered a greater degree of desilication than others? I agree with Smyth that the principal factor in bringing the reaction about was a local concentration of the volatile constituents of the magma; but that concentration does not itself account for the presence of nepheline in the rock.

From the actual instances of desilication which I have cited above, I draw the following conclusions:—

(1) That typical ijolites, malignites, jacupirangites, and the diopside-rich shonkinites and pyroxenites are characteristic products of the assimilation of limestone; and

(2) That the four minerals melanite, cancrinite, pectolite and melilite are sure indicators of the same reaction.

But these deductions at once reopen the question of the supposedly "unfavourable" occurrences that were enumerated above. The malignites of Poohbah Lake are exactly like those of Loch Borolan and Sviatoy Noss; the ijolites of Kuusamo are identical in every minute detail with those of Sekukuniland and Fen and Magnet Cove; ijolite and theralite occur in the heart of the Kola intrusion (Umptek or Chibina); and the Turja rocks are typical ijolites and malignites, often holding much melilite, melanite and pectolite, and associated with "carbonatite" dykes. There is accordingly the strongest reason to suspect that reaction with limestone has taken place at these localities. In view of my own observations at Loch Borolan and Sekukuniland I have no hesitation in predicting that further work at Poohbah Lake and Kuusamo will eventually furnish evidence of the presence of limestone in contact with the alkaline eruptives at each place. The same conclusion may be extended to Turja, which brings the whole Kola Peninsula under suspicion. It is significant that the batholith is disappearing more and more from geology and floored intrusions are taking its place. For Almunge and for Red Hill a concealed limestone floor is no more impossible than it is for Alnö and the Bushveld complex.

Having shown that Daly's theory is valid in certain cases, and either probable or at least possible in many more, it only remains to ask whether there is any alternative theory which rests on a surer basis.

In the theories of Harker, Evans, Smyth, and in the first theory of Bowen, the alkaline rocks are regarded as residues from the crystallization of larger bodies of sub-alkaline magma, separated either by compression (the "squeezing of the sponge"), by settling of the early-formed crystals, or by relief of pressure consequent upon the opening of channels in the roof. I do not question the effectiveness of any of these processes in separating residual magma, *but they are incapable of producing a felspathoidal residue from a magma that is not already undersaturated with silica.* It is a matter of elementary field experience that residues from the crystallization of granitic or gabbroic magmas are always highly siliceous. Granites give quartz-felspar pegmatites and quartz reefs; gabbros give interstitial micropegmatite, quartz-bearing aplites, and pockets of pegmatite. Of the four authorities named, Bowen alone has tried to show how the excess of silica may be disposed of. His first suggestion depended on the early crystallization of quartz from the magma, leaving a residual liquor with insufficient silica to form felspar. But this is so completely opposed to all field experience that it need not be considered further. Bowen's later theory is discussed separately.

It is true that Harker and Evans both postulate "further differentiation" of the residual magma after separation from the crystals, but they do not show how that residual magma can be so deprived of silica as to give rise to felspathoids instead of felspars. Smyth simply *assumes* that in the course of crystallization of a basaltic magma "the silica content starts low, rises to a maximum, and then sinks to a second low point". How the silica content comes to vary in this way we are not told ; yet that is the crux of the whole matter.

In short, the theories just referred to lead us to soda-rich granites and pegmatites ; they do not lead us to felspathoidal rocks.

In addition to Daly and Smyth, the following petrologists attach special importance to magmatic gases and solutions in controlling the formation of alkaline rocks : Per Geijer, Arthur Holmes, W. G. Foye, Tom Barth, J. L. Gillson, V. Goldschmidt, E. Lehmann. Holmes supposes that "a portion of the magma specially rich in water and silica tends to move upwards . . . leaving a desilicated portion in which the crystallization of nepheline would proceed". If this were true it should be applicable to all intrusions, and desilicated rocks should be enormously commoner than they are. Tom Barth deals with a mother-liquor rich in alkalies and calcium carbonate, but does not express any opinion as to the source of the latter constituent. J. L. Gillson connects the genesis of alkaline rocks with the post-magmatic process of albitization by soda-rich solutions. His view is that alkaline rocks began to crystallize as sub-alkaline ones, but during the process of crystallization the magma became enriched with soda, and after consolidation parts of the rock were invaded by soda-rich liquids, the felspars were albitized, and soda-bearing minerals such as sodalite, cancrinite, riebeckite, and aegirine were formed. In so far as albitization has undoubtedly taken place in many foyaites, and evidence of reaction and replacement is abundant in such rocks, Gillson's view is well founded ; but it fails, like all the others, to account for the deficiency of silica which alone can cause felspathoids to be formed. W. G. Foye's view is similar to Gillson's, but Foye derives his soda-solutions from reaction between granitic magma and limestone, in full acordance with Daly's theory. Per Geijer and others emphasize the importance of magmatic fluids, but do not discuss their source or show how they can cause the production of felspathoids in a magma which is not already undersaturated with silica.

Thus *every one of the theories mentioned breaks down at the same hurdle. Daly alone shows us how it can be crossed.*

It only remains to discuss the latest theory propounded by my ingenious friend, N. L. Bowen, in his *Evolution of the Igneous Rocks*—a book which puts petrology on a higher plane than it has ever occupied before.

From the presences of mantles of "orthoclase" about crystals of basic plagioclase in certain rocks, Bowen deduces a reaction relation between orthoclase and anorthite, and shows accordingly that if, during the crystallization of a body of basaltic magma, the liquid is separated from the early-formed plagioclase crystals, that residual liquid will be enriched with orthoclase.

Before following Bowen any further I must point out that as far as my experience goes the mantles around basic plagioclase crystals are not really orthoclase or potash-felspar, as Bowen supposes, but a very soda-rich anorthoclase, which alters the case vitally.

From this residual magma leucite is now supposed to crystallize. Bowen says, however, that if much albite is present then crystallization of leucite will not take place. It seems to me that this admission upsets the whole case, since the anorthoclase-rich residue may hold more albite than orthoclase.

We are now asked to suppose that in consequence of the sinking of leucite crystals, or the straining-off of the remaining liquid, part of the magma becomes enriched with leucite while the other part contains a corresponding excess of silica. On cooling, the leucite crystals will transform to orthoclase and nepheline (pseudoleucite), and will give rise to a foyaitic type of rock which may or may not contain leucite in addition to nepheline.

Bowen does not follow the history of the leucite-impoverished fraction, which would presumably be much the larger part of the magma. It would crystallize, it seems as an orthoclase-plagioclase-silica aggregate such as a quartz-syenite or quartz-diorite; and I take it to be a necessary consequence of the theory that every foyaite should be accompanied by a larger body of quartz-syenite or quartz-diorite. This is only one of many points where the theory fails to fit the facts.

It will be observed that for the development of a foyaitic fraction from a basaltic magma Bowen's theory demands a remarkable conjunction of favourable circumstances. The liquid must twice be strained off from the early-formed crystals, and in each case this must happen at a crucial moment, after crystallization has proceeded far enough to produce the desired effect and before the temperature is reached at which reaction would set in and destroy the effect. If Bowen's postulates are all granted, it seems that a very small body of foyaite might originate in this way, say once in a million times; but to suggest that all nepheline rocks have been generated under such remarkable conditions is to put a far, far greater strain on the probabilities than the most extreme supporter of the assimilation theory has ever done.

The field-evidence which Bowen cites in support of his theory need not detain us long. The points that suggest the possibility of the intervention of leucite at Loch Borolan are insignificant in comparison with the facts that demonstrate the assimilation of limestone. The limestone is there to be seen, and the rocks nearest to it are all greatly enriched with lime. Even if we could remove from these rocks the diopside and the melanite which are products of assimilation of lime, restoring to the magma the appropriate amount of silica, it seems certain that the original magma would prove to be a quartz-orthoclase-albite one, not very different from a granite. If leucite can crystallize from such a magma, then it can crystallize from any granite magma anywhere !

Bowen next quotes the Ilimausak batholith, where Ussing found large crystals of analcime in lujaurite. Bowen says that " Ussing presents reasons for believing " that these crystals were formerly leucite. But Ussing gave no reasons ; he simply said that " as they behave like phenocrysts it *seems unlikely* that they are primary analcime crystals ". Since Ussing contends that the lujaurite magma was very rich in volatile substances and had a very low temperature of consolidation I suggest that Bowen's own studies of the orthoclase-leucite transformation afford the best evidence that the crystals in question were never leucite at any time in their history.

Surely I need go no further ! Bowen's newest theory has the brilliance that one associates with all Bowen's achievements, but it can only work under special and quite extraordinary conditions, which have probably never been realized outside of a laboratory.

It is not the case, then, that we have a choice between Daly's theory and half a dozen others of equal or greater probability. Up to a certain point Daly's theory has been proved to be correct ; beyond that point the choice lies between Daly's theory and no theory at all.

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REVIEWS.

THE COLONY OF FIJI, 1874–1929. pp. 198, with many illustrations and a map. Government Printer, Suva. 1929.

THIS well-written and well-illustrated Government publication gives a full and comprehensive account of the colony from almost every possible point of view. In most ways it seems to be an attractive place and the scenery is undoubtedly very fine. The section on geology and mining only runs to six pages, but is useful. Broadly speaking, the chief formations are: a metamorphic and plutonic basement series; Tertiary volcanics; reef limestones and alluvium. The age of the basement rocks is unknown, but they need not be very old, since in the more active regions of the earth such may be as late as Cretaceous, at any rate. The Fiji island group seems to form part of the New Caledonia–New Zealand arc, though it lies rather far to the east. The later volcanic rocks include andesitic and basaltic series, the latter being probably the older. The greater part of Vitilevu is covered by a horizontal " soapstone " formation, believed to represent marine tuffs. In some places andesite flows and fossiliferous Tertiary limestones are interbedded with it.

Mining in the islands seems to be embryonic, but it is believed that further prospecting is justified.

THE MINES OF MENDIP. By J. W. GOUGH. pp. viii + 269, with 2 folding maps. Oxford: Clarendon Press, 1930. Price 15*s*.

THIS book is essentially a study in the economic history of an ancient industry now extinct. The section on geology, though very brief, is correct so far as it goes: a few more capital letters would have been a great improvement; e.g. " old red sandstone " looks odd. It is interesting to notice that it is stated that nearly all the zinc was in the form of calamine (carbonate) in the Dolomitic Conglomerate. This suggests upward translation of the more soluble zinc compounds during a process of oxidation, while the less soluble lead ores remained in the Carboniferous Limestone. There was a great deal of mining in Roman times, and it looks very much as if the Romans had cleared away nearly all the good stuff, as most of the later attempts seem to have been singularly and monotonously unsuccessful. This, however, is not the place to review the historical side of this interesting book, which should be read by all concerned with British mining.

L'ŒUVRE DE SVEN HEDIN ET L'OROGRAPHIE DU TIBET. Par EMM. DE MARGERIE. Extrait du *Bulletin de la Section de Géographie* du Comité des Travaux historiques et scientifiques, 1928. Paris : Imprimerie Nationale, 1929.

IT is impossible to review a review, even when, or perhaps especially when, it is a whole book. The only thing to be done is to draw attention to its existence. This volume of 139 pages with 28 figures is a summary and criticism of Sven Hedin's gigantic work in nine volumes on Southern Tibet, which runs to 3771 pages with 599 plates, 98 maps, and an incredible number of sketches ; a work so large and costly that probably few will ever see it. This masterly summary by perhaps the most competent of living authorities cannot fail therefore to perform a most useful service.

GEOLOGICAL STRUCTURE OF THE SOUTH-WEST PORTION OF THE SUDBURY BASIN. By E. S. MOORE. *Trans. Canadian Inst. Min. Met.*, 1930.

THE recent development of the Treadwell-Yukon zinc-lead deposits in the south-west part of the Sudbury basin has led to an extensive study of the faulting in that area, which is clearly in genetic connection with the mineralization. Professor Moore indicates that the zinc-lead ores belong to a late hydrothermal phase of the differentiation of the nickel eruptive ; and their localization was controlled by orogenic movements that produced extensive thrusting and shearing in the Sudbury region, with intrusion of dykes, some of which cut the norite and micropegmatite. Some of the faults have a displacement of five or six thousand feet. This is an important contribution to the geology of a most interesting area, which has given rise to much controversy.

METHODS IN GEOLOGICAL SURVEYING. By EDWARD GREENLY, D.Sc., V.P.G.S., and HOWEL WILLIAMS, M.A., D.Sc. pp. 1–420, with one coloured map and numerous illustrations in the text. London, T. Murby and Co., 1930. Price 17*s*. 6*d*.

READERS of the GEOLOGICAL MAGAZINE will acknowledge that a book on this subject by these two authors merits attention for they will remember Greenly's single-handed achievement in the mapping of Anglesey and the excellent map of Snowdon published by Howel Williams. It is, therefore, a pity that the book as it stands contains so much matter that seems irrelevant to the subject. The history of the evolution of geographical mapping in general and geological mapping in particular, which occupies the whole of Part I, has no doubt an interest of its own, but its place does not seem to be here, and throughout the book there is a tendency to discursiveness which distracts from the main topic.

The really valuable part of the book is contained in Part II, and though here also much could have been got from other publications on topographical surveying, it is no doubt convenient to have it all together, and every young geological surveyor would do well to read and assimilate the excellent advice here given. The aim of the book, as the authors state in the preface, has been to encourage mapping *for its own sake*, as an end in itself rather than a means to an end. They emphasize the need for the separation of facts of observation from those of inference, and for exactitude in the location of evidence. With all these things geologists will be in complete agreement, for the most important thing with which the geological cartographer should be concerned is the accurate recording of *actual facts*. Geologists of succeeding ages may, and probably will, differ in the interpretation of many of these facts, but the valuable thing is their impartial recording. We do not quite agree with the authors' time-estimate of the value of such records, for undoubtedly, with the lapse of even relatively few years, outcrops become overgrown and concealed in many ways, and may even be deliberately destroyed, so that no matter how great the care lavished on its construction a map is only really accurate for a very short time. All the more reason, though, for accuracy at the time of its construction ; its value lies in the reliability that can be placed upon the surveyor's work, since his records become historical documents. Nothing, naturally, in the vast majority of cases, can compare for accuracy with direct observation in the field, yet we think the authors are somewhat unduly contemptuous of geometrical constructions, which when based upon field observations have been shown by Busk to serve a most useful purpose in the location of underground structures, the accuracy of which has been put to a practical test over and over again. No amount of field surveying alone could have given these results. So, too, a certain amount of the authors' despised " calculator surveying " has been proved over and over again to have a distinct value both as a preliminary to initial efforts in field survey, and accompanying such survey, since it helps students to realize very clearly the dependence of outcrop upon topography, and also the most important adjunct of " seeing solid ", i.e. in three dimensions. The authors' views upon actual methods are perhaps coloured too highly from the character of the country where their own work has been done, for provided the result aimed at is the same, it is, we think, a mistake to be too dogmatic as to the actual method to be followed. It would seem to be better to leave the selection of exact detail to individual choice since it must vary very largely with the nature of the ground to be surveyed and the character of the map required. The same end may be attained by many different ways. In zonal mapping, for example, the reviewer has often found it useful to indicate exact localities by a fine pin-prick and to number these on the back of the map where also palaeontological notes may be made relating to such localities; other geological details being noted on the front; but she can imagine that such a proceeding might be regarded as a desecration by the senior author! More insistence might have been made throughout the book upon the importance of adding to the topographical map by the insertion of form lines or by freehand sketches in order to bring out greater detail concerning the shape of the ground than is afforded by contour lines 100 ft. apart. Such records are often invaluable in the subsequent interpretation of other noted facts, and are especially so in dealing with superficial deposits and accumulations. The book is well got up, and the illustrations are for the most part well drawn and clearly reproduced, but we cannot help thinking that the authors' methods would have been better illustrated by a map other than the one chosen for the frontispiece, which is difficult to follow even with the aid of an appendix, which surely should not be needed, and we do not think figures 70*c* and 70*d* give a very accurate representation of the state of things in what the younger author terms "transgressive overlap" and "regressive overlap".

G. L. E.

LA LORRAINE METALLURGIQUE. By AXEL SÖMME. pp. 225, with plates and maps. Berger-Levrault: Nancy, Strasbourg, and Paris, 1930. Price 30 francs.

THERE is hardly any geology in this book, but it is of great interest to economic geologists as giving an account of the development and present position of the iron and steel industry of Lorraine and its relation to the similar industries of neighbouring countries. The author is a Norwegian professor, presumably of economics, who has no political axe to grind, and the book is entirely the result of personal investigations on the spot. It may therefore be accepted as authoritative and impartial.

R. H. R.

THE ORIGIN OF THE MID-ATLANTIC RIDGE. By H. S. WASHINGTON. Journ. Maryland Acad. Sci., vol. i, No. 1, pp. 20–9, 1930.

ALTHOUGH very short, this paper is certainly important. Its object is to point out that recent writers have ignored St. Paul's Rocks, a group of small islets one degree from the Equator at bout 29½ degrees west, which must have an important bearing on the subject. These rocks, which stand just on the ridge in its peculiar E.–W. portion, consist of a schistose peridotite, the only plutonic and metamorphic rock known in place in any of the islands on the ridge. The author is inclined to explain the ridge, on a hypothesis long ago put forward by a Belgian writer, Prinz, and supported by Dana: this hypothesis depends on differential torsion between the northern and southern hemispheres, and is consistent with the tetrahedral theory of Lowthian Green. It is to be regretted by English readers that the paper is published in a journal which will be accessible to few.

ELEMENTS OF OPTICAL MINERALOGY. Part III, Determinative Tables. N. H. WINCHELL AND A. N. WINCHELL. 2nd Edition, by Prof. A. N. WINCHELL. pp. xii + 204. London: Chapman and Hall, 1929. Price 22*s.* 6*d.*

THIS part completes the new edition in three volumes (a third edition of Part I having meanwhile appeared). The value of any new set of determinative tables is dictated partly by the amount of new information which they incorporate and partly by the special readiness with which they lend themselves to practical use. The data of Part II (to which this part forms an almost indispensable supplement) are here summarized with a completeness which scarcely justifies the retention of the title of "Elements". The tables are applicable both to thin slice work and to immersion methods, including double variation. Any attempt at compactness has been sacrificed in favour of devices which are claimed to lead to special facility in use.

F. C. P.

SIMPLE GEOLOGICAL STRUCTURES. By PLATT AND CHALLINOR. Murby and Co. Price 3*s.* 6*d.*

THIS little book, which is intended to be a companion to the *Exercises upon Geological Maps*, previously published by one of the authors, contains some useful information for the student of Elementary Geology, apart from the sections dealing with faults and folds, which are not successful in their treatment. Most of the remarks on faults are true of dip faults only, or of those faults in which there is a large component of dip; there is no reference to the effect of strike faulting and its effects upon outcrop, a most unfortunate omission from the point of view of the student. In dealing with folds attention should have been directed to the fact that we are not really dealing here with *plane*, but with *curved* surfaces, and we feel sure that in Nature folds hardly ever occur with the angularity shown by the authors. The sections are clear but are horribly unnatural; students should be encouraged from the outset to draw sections that have a natural appearance.

G. L. E.

LA STRUCTURE DU BASSIN HOUILLER DE LA SARRE. By P. PRUVOST. *Revue Universelle des Mines*, **7**, xvii, 61, 1928.

IT is not proposed to give here a full account of this interesting paper, but merely to point out that Professor Pruvost has shown the existence in the Sarre coalfield of a great fault very similar to parts of the Faille du Midi, but differing notably from this in the fact that the overthrusting is here directed towards the south. Furthermore, in this region, with its continuation into Lorraine, the stratigraphical succession is much more complete than in the north of France and Belgium, including the Stephanian Ottweiler beds, which, however, are separated from the Westphalian coal-measures by a transgressive basal conglomerate indicating the beginning of earth movement in this region. No Lower Carboniferous strata are seen in the Sarre, as the structure is anticlinal, and there is some faulting, perhaps of Tertiary age.

THE VOLCANIC DOMES OF LASSEN PEAK AND VICINITY, CALIFORNIA. By H. WILLIAMS. *Amer. Journ. Sci.*, xviii, 313. 1929.

IN the wide field of American vulcanological literature it is difficult to select papers for review in the limited space available in this Magazine, moreover, the *American Journal of Science* is to be found in most geological libraries in this country. Nevertheless, the subject matter of this paper appears to be of exceptional general interest. It deals with an important feature of vulcanicity whose significance has only been generally recognized since the eruption of Montagne Pelée in 1902, namely, the protrusion of lava as spines or domes in an already solid form. Around Lassen Peak in California the existence of thirteen such domes is described, the latest being not more than 200 years old. Comparisons are drawn between these and similar recent phenomena at Santorin and Santa Maria in Guatemala, with references to the eruption of Bandaisan and various vulcanological events in Alaska and elsewhere.

From the descriptions given it is clear that one of the most potent effects of such eruptions is the production of agglomerates of enormous magnitude, due to the shattering of such protruded masses, with blocks of colossal size. One is tempted to wonder whether the much-vaunted vulcanicity of the earlier ages has ever produced anything on so great a scale. Such have apparently not been found, and the obvious corollary is suggested that the volcanic activity of the earth is increasing, and not diminishing, as appears to be often assumed. Possibly it is changing in character rather than in potency, so that phenomena of a new kind are being manifested.